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Development and Commercialization of High Power Filter Press

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Abstract

Plant & Machinery Division (PMD) of Nippon Steel has developed and commercialized a High Power Filter Press in which a higher dewatering efficiency than conventional dehydrators is realized by designing higher slurry charging force. The new filter press offers measures for reducing the volume of slurries the variety and amount of which are increasing recently in various fields of industry and measures for effectively recycling them. This report describes development and commercialization of the new High Power Filter Press.

1. Introduction

In recent years, the volume reduction, efficient disposal, and effective utilization of slurries from various industries have become important issues. Aiming at the development and commercialization of a high-performance dewatering machine, the Plant & Machinery Division of Nippon Steel Corporation (NSC) started work on the development and commercialization of a high-pressure dewatering filter press, and eventually completed one. As compared with conventional filter presses, vacuum filters, and belt presses, the new high-pressure filter press has the slurry feed pressure set at a high value of 3.9 MPa (40 kgf/cm^2) during filtration and is characterized by high dewatering performance.

NSC's Plant & Machinery Division introduced technology concerning a prototype model of high-pressure filter press in 1989, and then carried out work on the commercialization of the technology. In 1991, the division entered the dewatering machine market with the sale of the first commercial model of high-pressure filter press. While pushing ahead with development efforts aimed at reliability improvement, equipment automation, and cost reduction, among other purposes, the division gradually expanded high-pressure filter press applications and market size. Today, NSC's high-pressure filter presses are extensively used in various industrial fields.

The high-pressure filter press can achieve higher treatment performance, formation of dewatered cake of higher strength, and lower running cost than conventional dewatering machines. Its applications cover a wide spectrum of industrial areas, including the disposal of tunnel drilling shield slurries, dredged sludge, waste solutions from manufacturing factories, and crushed stone washing slurries from quarries. The high-pressure filter press is creating new markets with its unique technology of dewatering slurries with high pressure.

This paper describes the development and commercialization of the high-pressure filter press, presents examples of high-pressure filter press applications to actual projects, and discusses the future outlook for the high-pressure filter press.

2. Outline of High-Pressure Filter Press

2.1 Development and commercialization of high-pressure filter press

Filtration is the separation of a liquid-solids mixture into the liquid and solid components, and consists of the steps of pressurizing the liquid (slurry) containing many solid particles, forcing the slurry through a filter medium, and retaining the solid particles on the filter medium. Conventional filter presses can be classified into the low-pressure feed type and the expression type. With the low-pressure feed type, the slurry is fed by a centrifugal pump into a filtration chamber. The feed pressure is about 0.49 to 1.5 MPa. With the expression type, an expression membrane is provided between a filter plate and a filter cloth. The slurry is fed into the filtration chamber at

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a pressure of 0.49 to 0.69 MPa. The expression membrane is expanded by air or water, and the slurry is further expressed and dewatered. The expression pressure is about 0.7 to 1.5 MPa.

Recent years have seen mounting calls for dewatering difficult-to-dewater slurries and for decreasing the moisture content of dewatered cakes, increasing the strength of dewatered cakes and reducing the volume of dewatered cakes. There are an increasing number of cases that cannot be addressed by conventional types of dewatering machines in view of their performance. Prevention of environmental problems is also requiring the dewatering of slurries without addition of chemicals like filter aids.

The Plant & Machinery Division focused on the high-pressure dewatering technology to meet these social requirements, and pushed ahead with the development and commercialization of the high-pressure filter press.

2.2 Construction of high-pressure filter press

The flow sheet and general view of the high-pressure filter press are shown in **Fig. 1** and **Photo 1**, respectively. The main components are the high-pressure feed pump to produce a slurry pressure of 3.9 MPa and the high-pressure filter press to dewater the slurry. The high-pressure filter press system is equipped with various auxiliary devices as shown in the flow sheet. The slurry stored in the slurry tank is pressure-fed by the suction pump alone into the high-pressure filter press in the initial stage of the dewatering process. Then, the high-pressure feed pump is also started to dewater the slurry at the high pressure of 3.9 MPa. After completion of filtration, the dewatered cake is dropped onto the belt conveyor right below the filter press and carried out of the system. The filtrate water flows through the filtrate water collecting trough into the filtrate water tank. The slurry dewatering process consists of four steps: preparation, filtration, opening, and washing (only when the filtration performance of filter cloths is diminished).

(1) Preparation: The filter plates covered with filter cloths on both sides are pressed together to form the filtration chamber in preparation for filtration.
(2) Filtration: The slurry is pressure-fed into the filtration chamber and passed through the filter cloths for the separation of the slurry into solid and liquid components.
(3) Opening: The filter plates on which cake is formed are opened one by one to drop the dewatered cake onto the belt conveyor.
(4) Washing: When their filtration performance is reduced, the filter cloths are washed with high-pressure water to remove their surface deposits.

The opening and washing steps are automated by adoption of automation mechanisms (or automatic dewatered cake releaser and automatic filter cloth washer with high performance). Of the four steps, dewatering flow in the filtration and opening steps is shown in **Fig. 2**.

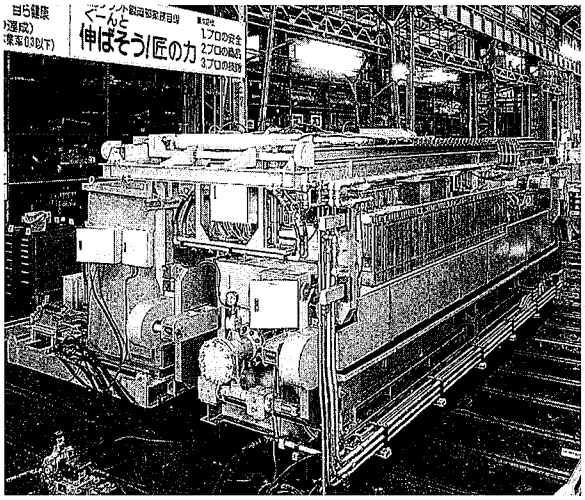

Photo 1 General view of high-pressure filter press

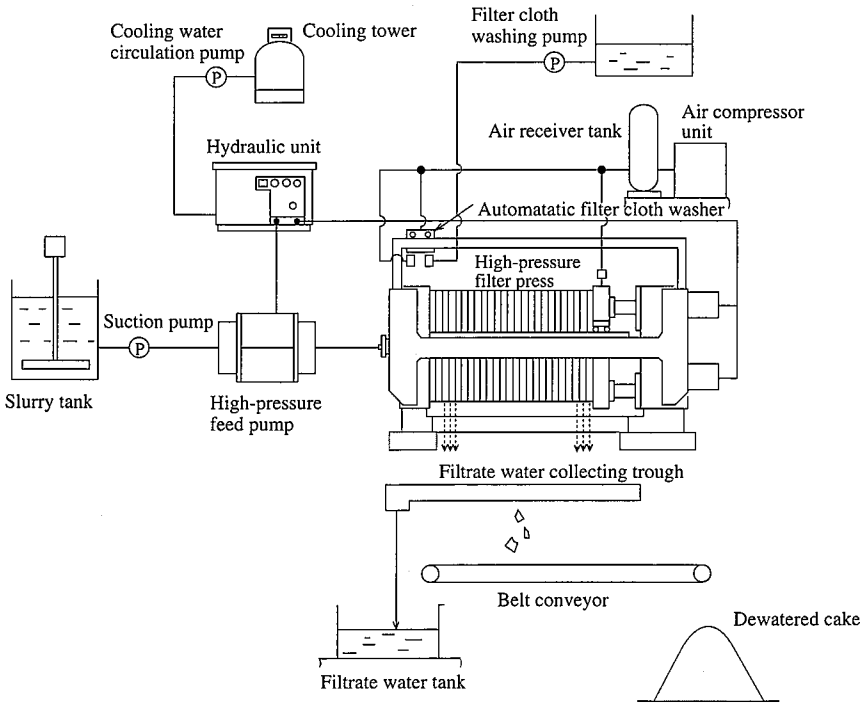

Fig. 1 Flow sheet of high-pressure filter press system

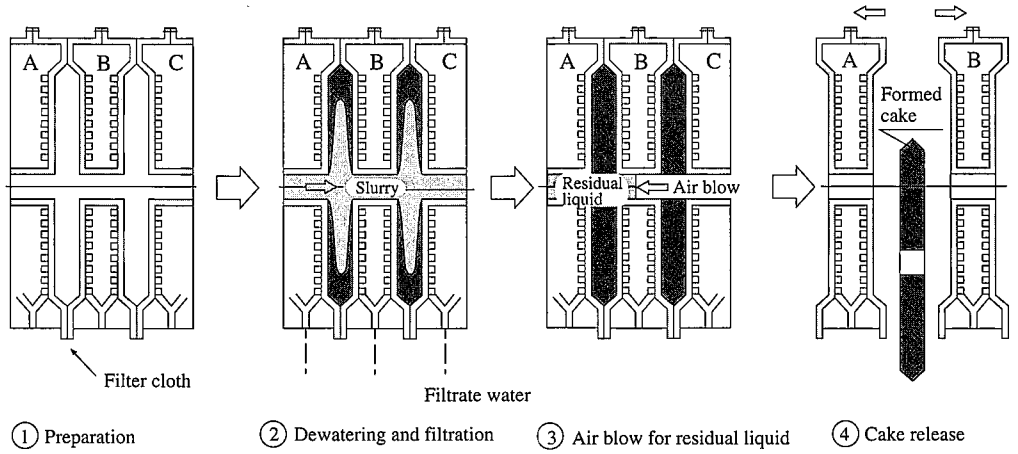

Fig. 2 Dewatering process flow sheet

2.3 Features of high-pressure filter press

2.3.1 Volume reduction of dewatered cake

The relationship between the dewatering pressure for various slurries and the moisture content of dewatered cakes is shown in **Fig. 3**. Dewatering proceeds by compacting the solid particles in the filtration chamber through pressurization and discharging the excess moisture through the filter cloths outside of the system. Increasing the dewatering pressure decreases the moisture content of dewatered cake at the completion of pressurization and at the same time, reduces the volume of dewatered cake. If the filtration resistance is increased by blinding of the filter cloths, the slurry feed pressure of 3.9 MPa can expand the dewatering region without drop in dewatering capacity.

2.3.2 Improvement in treatment capacity

The relationship between the dewatering pressure and time for various slurries is shown in **Fig. 4**. Generally, as the dewatering pressure increases, the dewatering time decreases. Slurries of high dewaterability are particularly susceptible to the influence of the dewatering pressure. The higher the dewatering pressure, the shorter the time required for the dewatering of the slurry, improving the slurry disposal capacity of the filter press. When a pressure of higher than 3.9 MPa within the pressure range of **Fig. 4** is experimentally applied, the dewatering time does not always shorten in many cases. Given economics, the rational dewatering pressure of 3.9 MPa is adopted as standard specification.

2.3.3 Effective utilization of dewatered cake

The relationship between the dewatering pressure for various slurries and the cone index of dewatered cakes is shown in **Fig. 5**. Consolidation of solid particles by the feed pressure in the filtration chamber tends to produce a dewatered cake of decreasing moisture and increasing strength with increasing dewatering pressure. The cone index is 0.78 MPa (8 kgf/cm^2) or more for the dewatered cake obtained by dewatering the tunnel shield slurry at the high pressure of 3.9 MPa. This value is greater than the strength specified for Class 2 of construction-generated soil under the "soil selection standard" of the Ministry of Construction. It suggests the possibility of the dewatered cake being effectively utilized as fill or backfill material in construction projects.

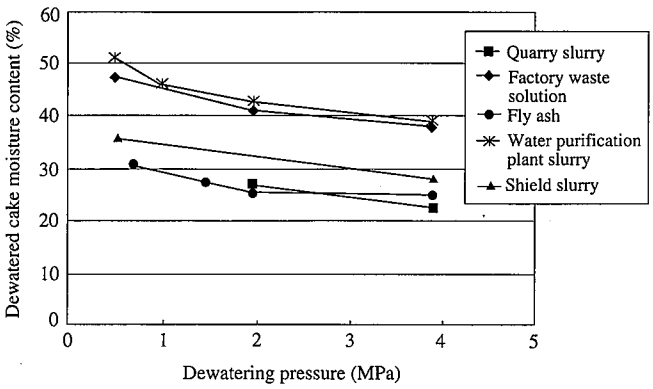

Fig. 3 Relationship between dewatering pressure and dewatered cake moisture content

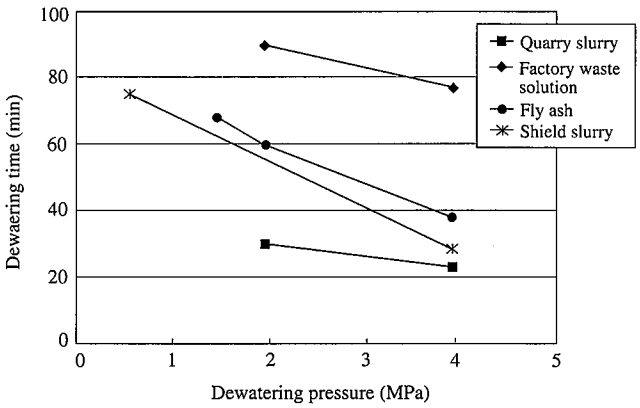

Fig. 4 Relationship between dewatering pressure and dewatering time

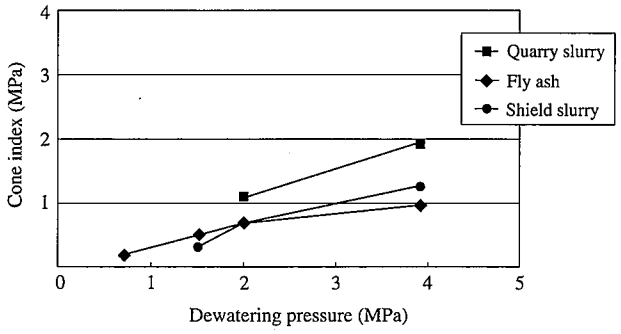

Fig. 5 Relationship between dewatering pressure and cone index

3. Development of High-Pressure Filter Press

3.1 Important development items

Establishment of the high-pressure filter press technology called for development of the following items:

(1) Development of dedicated pump for feeding slurry at high pressure of 3.9 MPa
(2) Development of filer press suited for high-pressure-fed slurry
- Development of slurry valves
- Development of filter cloths
- Development of automation devices

3.2 Development of high-pressure feed pump

Commercial slurry pumps are based on the principle that the impeller rotates within the casing to deliver the desired pressure. Their maximum feed pressure is about 1.5 MPa. A dedicated high-pressure slurry feed pump had to be developed for the high-pressure filter press. The structure of producing the feed pressure of 3.9 MPa by the expanding and contracting motions of rubber balls was adopted for the high-pressure feed pump.

The construction and general view of the high-pressure feed pump are shown in **Fig. 6** and **Photo 2**, respectively. Each high-pressure feed pump chamber is fitted with a rubber ball, and is divided into the oil chamber, intermediate liquid chamber and slurry chamber. The oil chamber is filled with hydraulic oil. The amount of hydraulic oil in the oil chamber is increased and decreased through the operation of hydraulic cylinders to expand and contract the two-layer rubber ball. This action of the rubber ball is combined with the operation of the slurry valve to suck and pressure-feed the slurry.

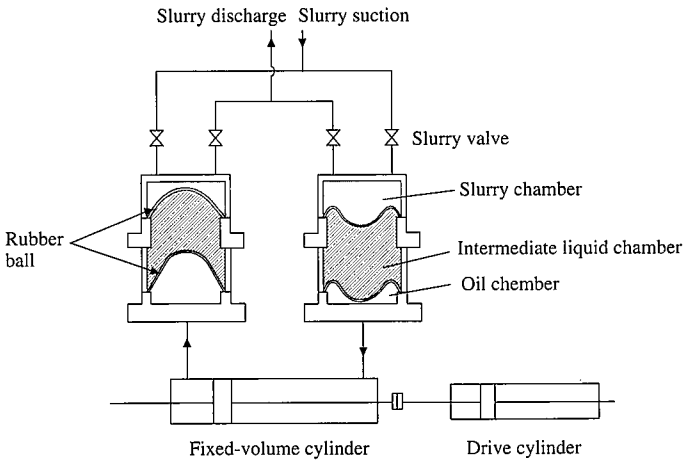

Fig. 6 Construction of high-pressure feed pump

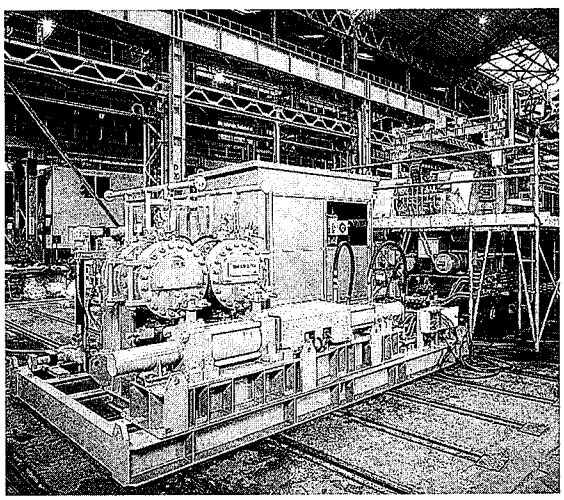

Photo 2 General view of high-pressure feed pump

The high-pressure feed pump in the initial phase of development had not long enough service life, and its development took a long period of time. After improvements upon improvements, such as rubber ball shape design, deformation behavior design, material design, tool and forming design, forming process review, and durability test, a service life that is long enough for commercial operation was achieved. Provision of the intermediate liquid portion helped to prevent the mixing of the slurry and hydraulic oil if the rubber ball broke. Equipment reliability was markedly improved as a result.

3.3 Development of slurry valves

Slurry valves are important components indispensable for shutting off the slurry flow to the high-pressure feed pump and controlling the slurry flow to the high-pressure filter press. Since valves capable of opening and stopping the slurry flow at the feed pressure of 3.9 MPa without leaks over a long period of time were not available on the market, development was carried out to solve the following technical problems:

(1) Ability to shut off a slurry containing solid particles like sand with practically no leaks
(2) Ability to operate a few tens of thousand times with respect to a slurry containing solid particles like sand

After many rounds of development, design and pressure testing in such areas as structural design, material design and operating practice, and after many improvements, slurry valves with functionality, reliability and durability satisfactory enough for practical use were successfully developed. Slurry valves now installed as standard equipment are the fourth generation. The general view of the slurry valve installed in the high-pressure feed pump is shown in **Photo 3**.

3.4 Development of filter cloths

The filter cloth is a basic part of the filtration performance of the filter press and is a factor that governs the automation of the filter press system. The filter cloth must satisfy the following thee main performance requirements:

(1) It must not blind.
(2) It must facilitate the release of dewatered cake.
(3) It must be strong.

Laboratory durability test, plant dewatering preliminary test, and plant on-line test were repeated on many prototypes with respect to three important development items, or filter cloth material selection,

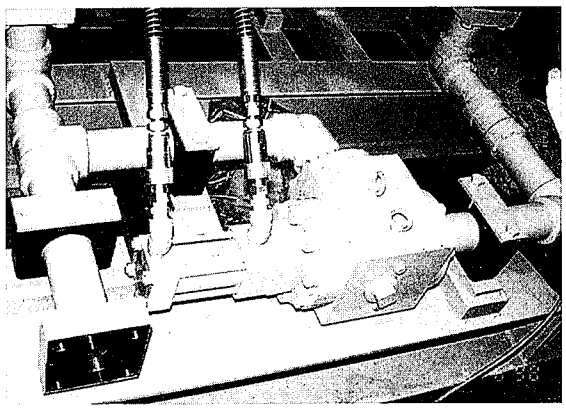

Photo 3 General view of slurry valve

shape design, and seal structure design. The filter cloths studied numbered a few tens of types. The following three types are now practically applied as standard filter cloths for the high-pressure filter press and are selected to suit specific applications.

(1) Filter cloth A: Tetron/multifilament filter cloth···Filtrate water clarity emphasized
(2) Filter cloth B: Nylon/multifilament filter cloth···Filtrate water clarify emphasized
(3) Filter cloth C: Nylon/multifilament filter cloth···Cake release emphasized

3.5 Development of automation units

3.5.1 Automatic dewatered cake releaser with high reliability

Release of the dewatered cake from the filter cloth is a key point for the automatic operation of the filter press. If some of the dewatered cake remains deposited on the filter cloth, the operation of the filter press may become unstable. The following methods were developed to achieve the automatic operation of the filter press:

(1) Method for releasing dewatered cake under its own weight from filter cloth by forcibly displacing filter cloth

This method proved somewhat effective in automatically removing the dewatered cake from the filter cloth, but was not high enough in reliability when the dewatered cake had a high moisture content or when the filter cloth was deteriorated in performance after long use.

(2) Method for releasing dewatered cake from filter cloth by using air

This method blows air against the dewatered cake for forcibly dislodging the dewatered cake from the filter cloth. It is effective also for the dewatered cake deposited on the filter cloth and has sharply improved the reliability of automatic cake release.

An automatic dewatered cake releaser that employs the above two methods in combination is installed as standard equipment on the high-pressure filter press. It ensures the release of dewatered cake.

3.5.2 Automatic filter cloth washer with high performance

As the dewatering and opening (cake discharging) steps are repeated, the dewatered cake and other solids from the slurry remain deposited or stuck to the filter cloths, plug the filter cloths, and reduce the dewatering performance of the filter press. Prevention of this situation called for development of a filter-cloth-washing unit. Preliminary experiments were repeated concerning the method of washing the filter cloths to suit the plugged condition of the filter cloths and the properties and distribution of solids stuck to the filter cloths. Washing parameters were determined and measured, and the following mechanisms were developed.

(1) Optimization of washing nozzle pattern

Nozzles capable of washing the entire cloth surface uniformly and efficiently are selected and arranged in an optimum pattern.

(2) Reduction in cycle time by row of traversing and rocking washing nozzles

A washing nozzle row traverses over the filter cloth surface, and then rocks up and down in preparation for washing the next filter plate. The filter cloths can be washed in a short time by combination of the traversing and rocking mechanisms.

(3) Nozzle traveling, traversing, and rocking mechanisms capable of proving arbitrary speed control

Nozzle traveling, traversing, and rocking mechanisms were adopted that allow the washing pattern to be easily set according to the degree of filter cloth contamination.

This design enabled the entire filter cloth surface to be washed uniformly and efficiently, the filter-cloth-washing time to be sharply reduced, and the filter cloths to be automatically washed. The high-performance, automatic filter-cloth-washer can clean the filter cloths in a cycle that is two times shorter than competitive machines made by other Japanese manufacturers.

The automatic dewatered cake releaser and automatic filter-cloth-washer are schematically illustrated in **Fig. 7**.

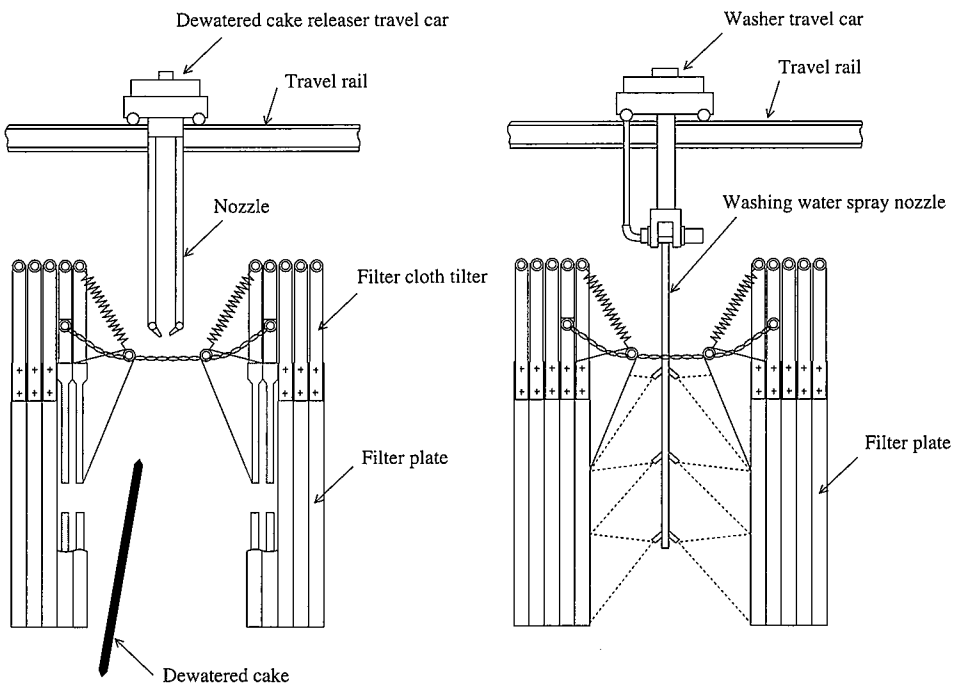

Fig. 7 Schematic of automatic dewatered cake releaser and automatic filter cloth washer

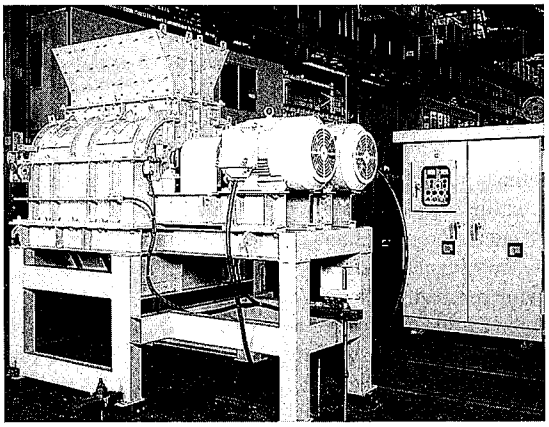

Photo 4 General view of dewatered cake disintegrator

3.6 Expansion and standardization of models

In parallel with development of various components for commercialization of the high-pressure filter press, we carried out the planning, designing, and manufacturing of dewatering equipment for actual projects. A series of high-pressure filter press models to meet dewatering applications in various industries were developed and standardized. Standard models in the filtration volume range of 0.15 to 6.8 m^3 are marketed for use in various applications. A medium-pressure filter press with a pressure specification of 2.0 MPa (20 kgf/cm^2) was also developed for applications where the high-pressure dewatering specification is not required.

Supplying dewatering plants (pretreatment and posttreatment) having high-pressure filter presses as nucleus equipment are also being worked on. Development and commercialization of dewatered cake disintegrators for effective utilization of dewatered cakes can be cited as one example. NSC's disintegrators are now available in standard models with a capacity of 20 to 120 tons/hour. Adoption of a dewatered cake disintegrator after the high-pressure dewatering process made it possible to obtain a disintegrated cake of uniform size continuously during belt conveyor transfer and to facilitate the volume reduction and reutilization of dewatered cakes. **Photo 4** shows the general view of a dewatered cake disintegrator.

For the details of the high-pressure filter presses and dewatered cake disintegrators, refer to NSC's catalogs.

4. Application Examples of High-Pressure Filter Presses

4.1 Shield slurry field

In the construction industry, many tunnels, such as for subways, sewer pipes, gas pipes, and water discharge channel pies, are excavated to make effective use of underground spaces. The slurry shield method is adopted in many large-scale tunneling projects, producing large amounts of surplus slurry. NSC's high-pressure filter press is used to dewater the surplus slurry. It can dewater the surplus slurry with no or minimum addition of coagulants, and produce a compacted, high-strength, dewatered cake in a short dewatering cycle. In recent years, the dewatered cake has been used as backfill material in the construction of very large river banks. The high-pressure filter press is expected to find increasing usage in such applications.

4.2 Dredging field

In the dredging field, sediments are dredged. High-moisture sediment is transported to a wide site where it is dried in the sun and mixed with cement for solidification. Sediments dredged from harbors, lakes, and dams, among other places, must be disposed of safely and properly now. NSC's high-pressure filter press is adopted to dewater such sediments. The machine enables the dewatering of the sediment in a safe, certain, and space-saving manner, produces a dewatered cake of low moisture and high strength, and allows the volume reduction of the dredged material. The dewatered cake is being put to effective use as road-bed material and upland field soil, and in many other applications.

4.3 Factory field

In the factory field, slurries from various manufacturing lines and waste solution treatment lines are dewatered. Our high-pressure filter presses are penetrating at a fast rate in this field as well. Manufacturing lines often require a drying process after the dewatering process, so that a dewatered cake of low moisture must be produced. Waste solution treating lines require the treatment cost to be lowered by reducing the moisture content and volume of dewatered cake. The characteristics of NSC's high-pressure filter press match these requirements.

The high-pressure filter press is adopted to dewater sludge from basic oxygen furnace (BOF) off-gas cleaning systems at steelworks. This sludge is dewatered to form a cake of low moisture and high strength. The dewatered cake can be effectively utilized as iron unit without sun drying. NSC's high-pressure filter press features higher treating capacity and maintainability than conventional filter presses. It is also used to dewater neutral sludge from metal coating lines at steel plants. Now that dewatered cake disposal sites have reached their acceptance limits, there are mounting calls for the volume reduction of dewatered cakes. NSC's high-pressure filter press has made it possible to reduce the volume of dewatered cakes, contributing to reduction in waste transportation and disposal costs.

4.4 Quarry field

The high-pressure filter press is used to dewater washing water from the wet quarrying process in which quarried stone is washed to remove fine adhering particles and improve its quality. In many cases, the quarried stone washing slurry is subjected to sedimentation in a basin at the quarry, and the resultant cake is dried in the sun. The increasing difficulty of dumping this material at landfill sites is increasing the mechanical dewatering of these slurries. NSC's high-pressure filter press is effective in reducing the volume of the quarried stone washing slurry and utilizing the resultant dewatered cake.

The high-pressure filter press allows the dewatering of the quarried stone washing slurry without additives and the formation of dewatered cake of high strength and low moisture. When a such process was adopted that adds cement to the quarried stone washing slurry and dewaters the resultant mixture under high pressure, a dewatered cake of high strength is formed for effective utilization as aggregate for sub-base course material and many other applications.

5. Conclusions

About ten years have passed since the high-pressure filter press business was entered. In the dewatering machine market, our high-pressure filter press is used in applications where it meets the requirements for dewatering difficult-to-dewater slurries without additives and for lowering the moisture content of, increasing the strength of and reducing the volume of dewatered cakes. It is creating a new value in the dewatering area dominated up to now by conventional filter presses.

The following activities for improvement of high-pressure filter press technology and for market expansion of said high-pressure fil-

ter presses are being carried out by the Plant & Machinery Division of Nippon Steel Corporation (NSC).

(1) Establishment of filtration theory

Filtration theory still has many unclear points and depends on empirical rules to a large degree. In the study of the application of our high-pressure filter press to dewatering a particular slurry, high-pressure filter press in the laboratory is used to dewater the slurry, dewatering data and press operating parameters are obtained, and a variety of analyses according to accumulated data are conducted. There are efforts being made to extract some rules from the accumulated data and to establish quantitative dewatering theory. They are gradually bearing fruit.

(2) Development of "new soil" process

The "new soil" process is designed to dewater slurry at high pressure by adding a conditioner (e.g., cement) to the slurry. This process will allow the effective utilization of dewatered cake as backfill or fill material. We are now promoting it as a process to add a new value to dewatered cake through the New Soil Research Committee.

Making use of abundant dewatering data accumulated by the Plant & Machinery Division, new applications for our high-pressure filter presses will be developed, and optimum products for the dewatering machine market will be developed and commercialized.