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Patent Analysis of the Application of Film Technology for Air Dehumidification

[1,]Chun-Wei Chen, [1,]Chun-Chang Li, [1,]Chen-Yu Lin

[1)]Taiwan Instrument Research Institute, NARL, 20, R&D Rd. VI, Hsinchu Science Park, Hsinchu, 30076, Taiwan, R.O.C.

Abstract: With the trend of energy conservation and carbon emissions reduction, methods for reducing the energy consumption of airconditioning systems through technological development has become a prevalent industry research topic. Studies have been conducted on the application of film technology on large airconditioning and dehumidification systems. This study performed a patent search through Taiwanese and US patent databases to analyze various technological development trends among competitive manufacturers. Through interviews with experts, this study established a technology classification fishbone framework for film dehumidification and used technical-analysis software for plotting a technical-efficacy matrixto serve as a reference for future research and development. The results revealed that film dehumidification technology has reached its inflection point of technical development and entered technical maturity. The primary patent owners were 7AC Technologies, Texas A&M University, and Daikin Industries. Currently, film patterns have the greatest number of patents (222), followed by runner-type devices (175) and humidification methods (134). Among film patterns, flat-type film has the highest number of patents (98); 79 patents have also been grantedfor hollow fiber tubes. Regarding humidification methods, mixed systems of film and a dehumidifying agent had the greatest number of patents (64), indicating thatcombining two methods may be the primary focus of future short-term development. For runner-type devices, straight-type technology had the greatest number of patents (119). In summary, this study concluded that few patents have been granted for tubular film, roll-type film, vacuum dehumidification methods, and Z-type runners but that breakthroughs regarding the technical gap for these technologies are possible. In the short term, using thin film to completely replace other humidification methods is infeasible. However, combining film and dehumidifying agents can be the focus of future short-term development.

Keywords: film, patent analysis, dehumidification, airconditioning

1. Introduction

1.1 Research Motives

Global warming has become an increasingly serious concern, and both energy conservation and carbon emission reduction have become common goals worldwide. Therefore, the development of energy-saving technology for air conditioning systems is a crucial research topic. The research team helped a technical team to fabricate a highly efficient and homogenized dehumidifying film and develop a testing technique. However,

several questions arose, such aswhether the distribution of related patents could be understood through patent searches prior to the development of a technology (e.g., whether a patentee is an independent inventor and how a company's research team is distributed according to country and company type).Other questions include whether some innovative ideas can be inspired by patent search during the development of a technology, whether patent search can help determine a patentable and avoidable design following the development of a technology, and whether a market and competitor analysis can help develop a commercialization concept. The aforementioned questions motivated the researchers to perform a patent analysis in this study regarding the application of highly efficient and homogenized dehumidifying films on air conditioning.

1.2 Research Purposes

The purposes of this study are as follows: 1. to understand the state of the art of related technologies and patents through a patent analysis; 2. to predict future trends and understand future development directions according to the current status of patent development; 3.to analyze and develop red and blue ocean strategies by drawing a matrix diagram of patented-technology efficacy and modify the strategy and direction of research and development (R&D).

2. Patent Search

This study performed a patent search on the Taiwan Patent Database and United States Patent and Trademark Office and plotted a patent management diagram to analyze patents and technology efficacy matrices through the patent search using IP-Tech software.

2.1 Patent Search and Selection Processes

2.1.1 Technical keywords

Table 1 lists technical keywords for the development of film dehumidification technology

Table 1 Technical keywords

keywords	English keywords
film	Membrane/Film
dehumidification	Dehumidifacation

2.1.2 Patent search strategy and results

Regarding patents for film dehumidification technology, this project used paid database services (i.e., M-Trends and IPTECH) and performed a patent search on public and announced patents in Taiwan and the United States. Table 2 presents the search strategy and results.

Table 2 Patent search strategy

Country	Search strategy	Number of patents	Selection results
TW	TAC: (“dehumidification”OR“moisture removing”OR “water absorption”OR “water removing”OR “humidity reduction”OR “humidify control”OR “humidity control”OR “liquid reduction”OR “water reduction”) and TAC: (“film”)	288	48
US	TAC:(dehumid* OR "remove moisture"OR "remove water" OR "absorb moisture" OR "absorb water"OR "lower humid*" OR "control moisture" OR "reduce moisture" OR"reduce water" OR "reduce liquid") AND TAC:(membrane OR film)	595	171

2.1.3 Film dehumidification technology classification

This study established a technology classification fishbone framework for film dehumidification by interviewing experts, scholars, and project team members (Fig. 1).

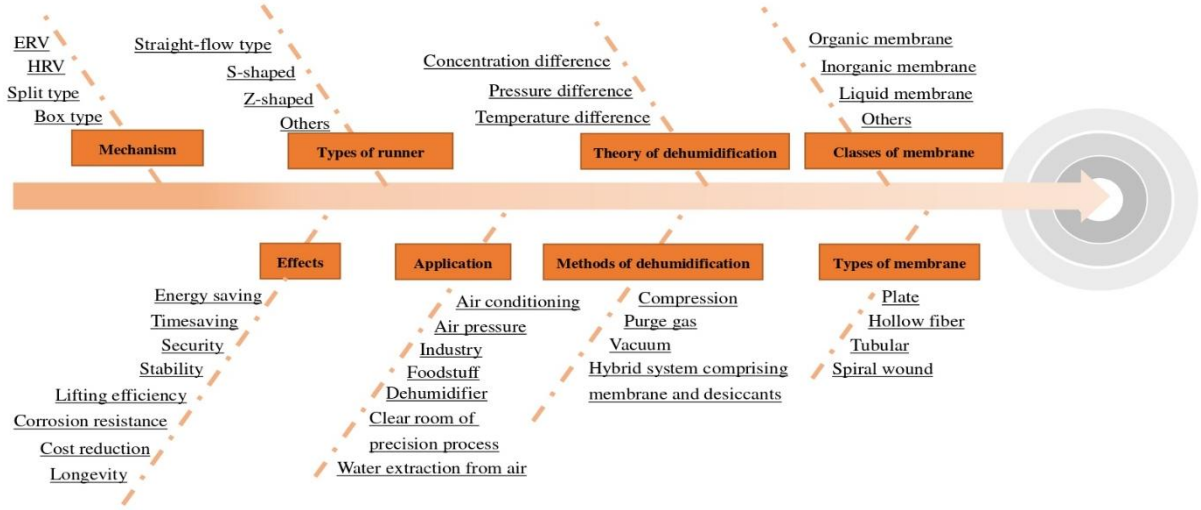

Figure 1. Technology classification fishbone framework for film dehumidification

3. Analysis of the Film Dehumidification Patent Management Diagram

3.1 Number of Patents

3.1.1 Technical development trends

Related patents have been receiving approval and publicity in Taiwan since 1980 (Fig. 2). In terms of patent application years, numerous patents have been granted since 2011, and more than three patents are typically publicized each year. In terms of patent announcement years, more than five patents were announced in 2017. In terms of patent publication years, more than eight patents were publicized in 2017.

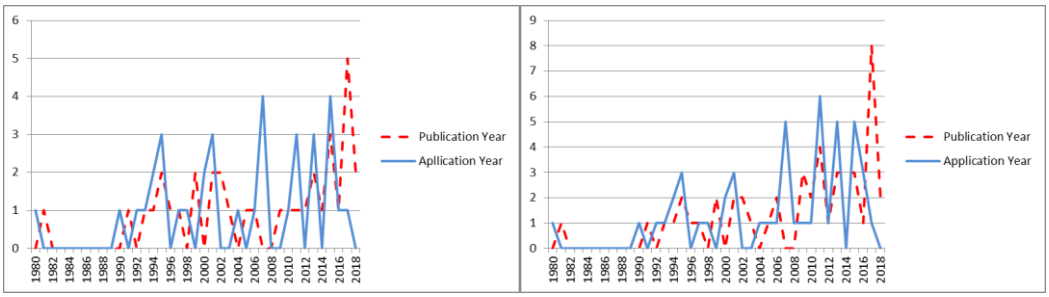

Figure 2. Trend in the number of patents for film dehumidification by year: approved (left)/publicized (right)

3.1.2 Analysis of technical life cycle

In 1975, film dehumidification technology entered technical infancy. The technology entered the technical growth stage in 2003 and reached the inflection point of technical development and entered technical maturity in 2012. Numerous products developed through mature film dehumidification technology are currently utilized. In addition, the mature technology is suitable for cross-domain applications (Fig. 3).

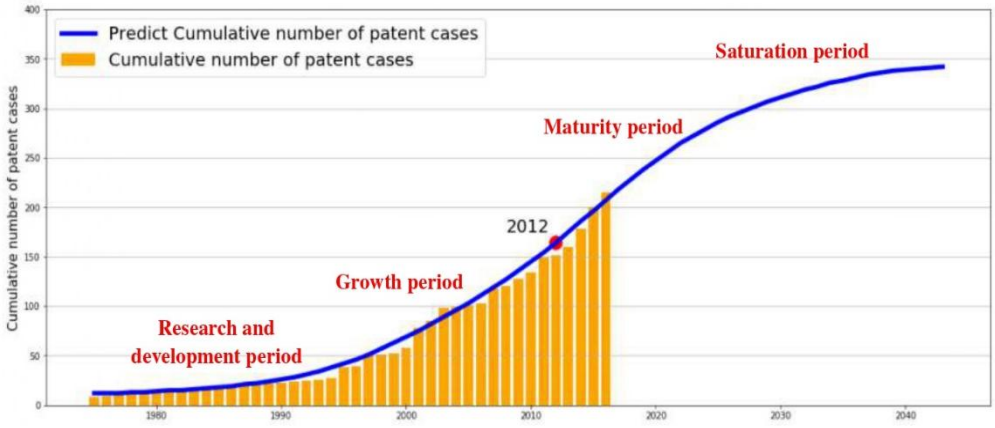

Figure 3. Technical life cycle

3.2 Country Type

3.2.1 Analysis of countries to which patents belong

Currently, the United States possesses the highest number of patents for film humidification technology, with a total of 76 patentees having applied for patents. Japan possesses the second highest number of patents (approximately 53 patents and 37 patentees). Taiwan has 22 patents and 14 patentees (Table 3).

Table 3 Numberof patents owned by various countries

Rank	Country	Number of patents	Number of patentees
1	US	107	76
2	JP	53	37
3	TW	22	14
4	GERMANY	8	8
5	KR	5	3

3.2.2 Trend in the number of patents owned by various countries

As shown in Fig. 4, the Unites States was the first country to develop patents for film humidification technology in 1975 and has the highest number of related patents, followed by Japan (53 patents) and Taiwan (22 patents).

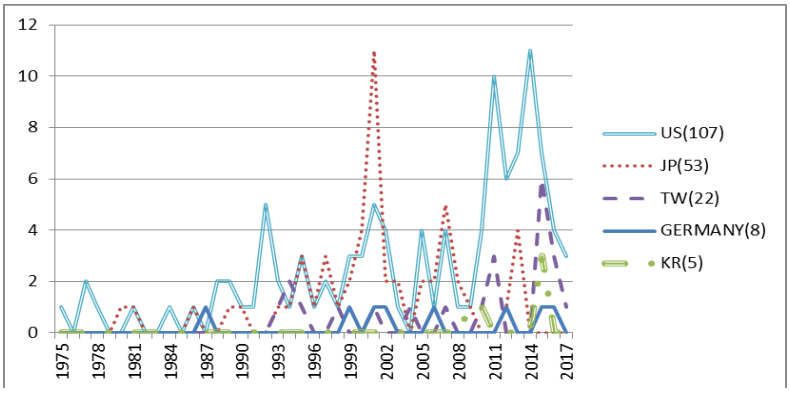

Figure 4. Trend in the number of patents owned by various countries by year

3.3 Analysis of Company Type

3.3.1 Company R&D capability

Table 4 lists data regarding the R&D capability of the top six companies concerned with film humidification technology. Table 5 presents the citation frequencies of the top four companies.

Table 4 Company R&D capability

Company	Number of patents	Active years	Number of inventors	Average patent age
7AC TECHNOLOGIES, INC.	14	5	6	2
The Texas A&M University System	6	2	3	4
DAIKIN INDUSTRIES, LTD.	5	4	8	12
JPMORGAN CHASE BANK, N.A.	4	3	10	17
Ali Mohammad Bujsaim	4	1	2	1
SMC CORPORATION	4	3	2	8

Table 5 Citation rates of companies

Citation	THE TEXAS A&M UNIVERSITY SYSTEM	7AC TECHNOLOGIES, INC.	ALLEN TELECOM LLC & COMMSCOPE, INC.	JPMORGAN CHASE BANK, N.A.
THE TEXAS A&M UNIVERSITY SYSTEM	0	0	8	0
7AC TECHNOLOGIES, INC.	14	8	0	0
ALLEN TELECOM LLC &COMMSCOPE, INC.	0	0	8	2
JPMORGAN CHASE BANK, N.A.	0	0	3	1

3.3.2 Analysis of the citation rate according to company type

Table 6 lists the citation rates of the top four patentees related to film humidification technology.

3.4 Analysis of International Patent Classification

According to the analysis of international patent classification (IPC), the top two IPC patents in Taiwan and the United States are B01D (defined as separation) and F24F (defined as air conditioning, air humidification, ventilation, and air flow as a screen application). Therefore, the key technology for film dehumidification concerns the separation of moisture from the air to achieve the optimal performance of film dehumidification.

Table 6 Citation rate according to company type

Patentee	Self-cited frequency	Frequency of citations by other patentees	Total number of citations	Frequency of citations by other patents	Technical independence	Citation rate
7AC TECHNOLOGIES, INC.	8	0	8	8	1	0.571
JPMORGAN CHASE BANK, N.A.	1	8	9	4	0.111	2.25
THE TEXAS A&M UNIVERSITY SYSTEM	0	14	14	7	0	2.333
ALLEN TELECOM LLC & COMMSCOPE, INC.	8	36	44	17	0.181	8.8
Average	2.428	8.285	10.7	5.142	0.184	1.993

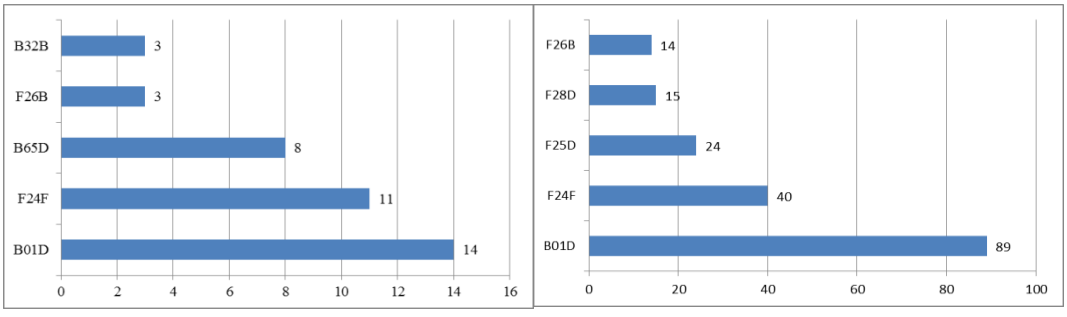

Figure 5. IPC patent analysis: Taiwan (left)/the United States (right)

According to the trend analysis by year (Fig. 6), the United States began rapid development in 1986, and Taiwan began substantial development only after 2001.

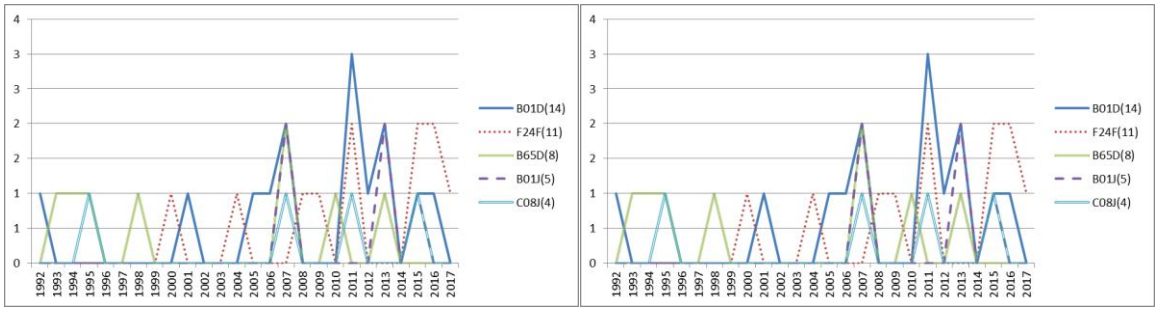

Figure 6. Trend analysis of crucial IPC patented technologies by year: Taiwan (left)/the United States (right)

3.5 Analysis of Patent Classifications and Trendsin the United States

According to the United States Patent Classification analysis for film dehumidification (Fig. 7), key technologies were gas separation (055), gas separation apparatus (096), and gas separation processes (095), followed by refrigeration (062) and drying and gas or vapor contact with solids (034). The trend analysis indicates that gas separation technology began rapid development in 1995.

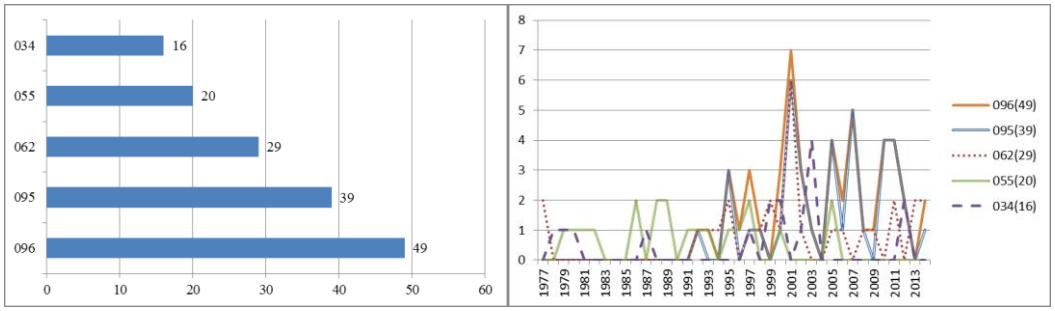

Figure 7. United States Patent Classificationanalysis and trend analysis

4. Analysis of the Technical Diagram for FilmDehumidification Patents

4.1 Current Status of Technical Development and Trends and Patent Layout

As indicated in Table 7, among the patents related to film-pattern technology, the second-order technical type of most patents is flat-type film; among the patents related to dehumidification technology, the second-order technical type of most patents is a mixed system comprising film and a dehumidifying agent; among related patents for runner-type technology, the second-order technical type of most patents isthe straight-type.

Table 7 Film dehumidification: number of patents according to film pattern/dehumidification method/runner-type classification

First order technology	Second order technology	Total number
Types of membrane	Plate	98
	Hollow Fiber	79
	Tubular	21
	Spiral wound	24
Methods of dehumidification	Compression	11
	Purge gas	36
	Vacuum	23
	Hybrid system comprising membrane and desiccants	64
Type of runner	Straight-flow type	119
	S-shaped	46
	Z-shaped	8
	Others	2

4.2 Matrix Analysis of Technical Efficacy

Tables 8–10 present matrices for the number of second-order technical patents corresponding to product applications and efficacy in terms of film pattern, dehumidification method, and runner type for film dehumidification. The following data reveals the direction and shortcomings of second-order technologies for film dehumidification.

Table 8 Film dehumidification: matrices for the number of patents corresponding to product applications and efficacy in terms of film pattern

Matrix of types of membrane and applications		Types of membrane			
		Plate	Hollow Fiber	Tubular	Spiral wound
Applications	Air conditioning	35	34	15	10
	Air pressure	1	0	0	0
	Industry	25	23	8	6
	Foodstuff	8	8	3	5
	Dehumidifier	20	9	2	2
	Clear room of precision process	0	0	0	0
	Water extraction from air	1	2	0	1

Matrix of types of membrane and effects		Types of membrane			
		Plate	Hollow Fiber	Tubular	Spiral wound
Effects	Energy saving	33	26	9	7
	Timesaving	3	6	1	1
	Security	4	2	0	1
	Stability	59	45	14	14
	Lifting efficiency	60	56	12	18
	Corrosion resistance	11	3	1	3
	Cost reduction	43	30	10	12
	Longevity	11	4	3	2

Table 9 Film dehumidification: matrices for the number of patents corresponding to product applications and efficacy in terms of dehumidification method

Matrix of methods of dehumidification and applications		Methods of dehumidification			
		Compression	Purge gas	Vacuum	Hybrid system comprising membrane and desiccants
Applications	Air conditioning	0	5	18	41
	Air pressure	0	0	0	1
	Industry	0	9	1	16
	Foodstuff	0	3	1	4
	Dehumidifier	3	6	14	8
	Clear room of precision process	0	0	0	0
	Water extraction from air	0	1	1	2

Matrix of methods of dehumidification and effects		Methods of dehumidification			
		Compression	Purge gas	Vacuum	Hybrid system comprising membrane and desiccants
Effects	Energy saving	2	12	11	26
	Timesaving	0	4	0	3
	Security	0	3	0	2
	Stability	7	12	21	39
	Lifting efficiency	3	23	21	54
	Corrosion resistance	0	0	0	13
	Cost reduction	3	12	13	26
	Longevity	0	3	0	3

Table 10 Film dehumidification: matrices for the number of patents corresponding to product applications and efficacy in terms of runner type

Matrix of types of runner and applications		Types of runner			
		Straight-flow type	S-shaped	Z-shaped	Others
Applications	Air conditioning	29	37	6	0
	Air pressure	1	0	0	0
	Industry	27	3	1	1
	Foodstuff	9	1	0	0
	Dehumidifier	19	12	1	0
	Clear room of precision process	0	0	0	0
	Water extraction from air	1	3	0	0

Matrix of types of runner and applications		Types of runner			
		Straight-flow type	S-shaped	Z-shaped	Others
Effects	Energy saving	31	24	3	0
	Timesaving	7	0	0	0
	Security	5	2	0	0
	Stability	59	35	5	1
	Lifting efficiency	74	40	7	2
	Corrosion resistance	8	12	3	0
	Cost reduction	42	21	1	1
	Longevity	14	0	0	0

5. Conclusion and Suggestions

5.1 Conclusion

5.1.1 Overview on patent development

Patent applications have been filed in the United States since 1975; in Taiwan, patent applications were not filed until 1980. In both countries, a substantial number of patents began being granted in 1992. The most prominent patentee, 7AC Technologies in the United States, possesses 14 patents (approximately 6%); this is followed by the Texas A&M University System in the United States (6 patents, approximately 3%), Allen Telecom & Comm Scope in the United States (5 patents, 2%), and Daikin Industries in Japan (5 patents, 2%).

5.1.2 Development of film dehumidification technology

In terms of the number of patents, for first-order technology, the number of patents is the highest for film patterns(222 patents), followed by runner-type devices (175 patents) and dehumidification methods (134 patents). In particular, the number of patents is the highest for flat-type film (98 patents), followed by hollow fiber tube (79 patents). Some patents have been granted for spiral roll-type film (24 patents) and for tubular film (21 patents). Regarding dehumidification method, a mixed system consisting of film and a dehumidifying agent had the greatest number of patents (64 patents), indicating that these two dehumidification methods can be the focus of short-term development. Regarding runner type, straight-type runnershad the highest number of patents (119 patents), followed by Z-type runners(8 patents).

For second-order technologies that continued to develop but had few patents, in terms of film pattern, flat-type films have been granted new patents annually since 2005 (98 patents). In addition,21 patents were granted for tubular films and 24 patents were granted for roll-type films. Both types of film began development in 2011. Regarding dehumidification method, technologies for a mixed system of film and dehumidifying agent began substantial development in 2011 (64 patents). However, among 11 patent applications for compression-method technology, only one patent has been granted since 2010. Among 23 patent applications for vacuum-method technology, 7 patents were granted from 2014 to 2017. Among runner-type technologies, straight-type technologies have undergone the most substantial development since 2011 (119 patent applications). Among 8 patent applications for Z-type technology, 5 patents were granted from 2013 to 2016. Figure 8 summarizes technologies that have continued to develop but had few patents.

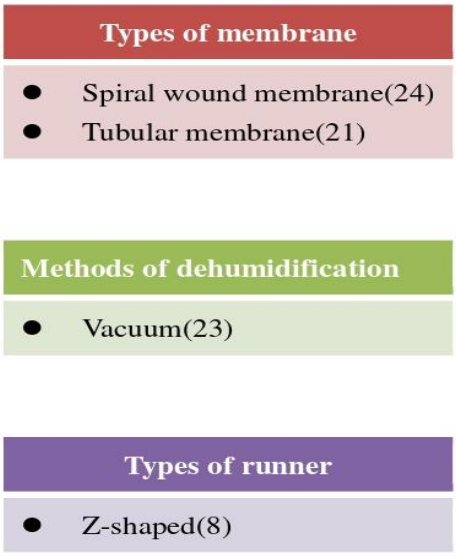

Figure 8 Few patents for film dehumidification and the gap in recent technical development

5.2 Technical Gap

According to Fig. 8, considering two aspects (the few patents and limited recent development), this study inferred that technical gaps lie in tubular film (21 patent applications), roll-type film (24 patent applications), vacuum dehumidification method (23 patent applications), and Z-type runner technology (8 patent applications). For these technologies, few patents have been granted but break through sare possible. We recommend filing patent applications for these technologies. In addition, patent applications for special performance and methods can be considered.

Acknowledgements

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