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POC-SCALE TESTING OF AN ADVANCED FINE COAL DEWATERING EQUIPMENT/TECHNIQUE

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MASTER

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EXECUTIVE SUMMARY

Froth flotation technique is an effective and efficient process for recovering of ultra-fine (minus 74 µm) clean coal. Economical dewatering of an ultra-fine clean coal product to a 20% level moisture will be an important step in successful implementation of the advanced cleaning processes. This project is a step in the Department of Energy's program to show that ultra-clean coal could be effectively dewatered to 20% or lower moisture using either conventional or advanced dewatering techniques.

The cost-sharing contract effort is for 36 months beginning September 30, 1994. This report discusses technical progress made during the quarter from January 1 - March 31, 1996.

OBJECTIVES AND SCOPE OF THE PROJECT

The main objective of the proposed program is to evaluate a novel surface modification technique, which utilizes the synergistic effect of metal ions-surfactant combination, for dewatering of ultra-fine clean coal on a proof-of-concept scale of 1 to 2 tph. The novel surface modification technique developed at the UKCAER will be evaluated using vacuum, centrifuge, and hyperbaric filtration equipment. Dewatering tests will be conducted using the fine clean coal froth produced by the column flotation units at the Powell Mountain Coal Company, Mayflower Preparation Plant in St. Charles, Virginia. The POC-scale studies will be conducted on two different types of clean coal, namely, high sulfur and low sulfur clean coal. The Mayflower Plant processes coals from five different seams, thus the dewatering studies results could be generalized for most of the bituminous coals.

APPROACH

The project team consist of the University of Kentucky Center for Applied Energy Research (UKCAER), Powell Mountain Coal Company (PMCC) and Andritz Ruthner Inc.

The UKCAER is the prime contractor of the project which has been divided into nine (9) tasks. The clean coal froth generated by the `Ken-Flote' columns at the PMCC Mayflower Preparation Plant will be utilized for dewatering studies using hyperbaric, centrifuge and vacuum dewatering techniques.

ACCOMPLISHMENTS DURING THE QUARTER

Laboratory vacuum dewatering tests conducted using the new design of filter leaf dewatering system indicated that for PMCC compliance coal use of cationic flocculant at a dosage of 15 g/t increased cake thickness from 3 to 8 mm and cake moisture from 23 to 26.8%; addition of 10 g/t of anionic flocculant increased cake thickness from 4 to 10 mm and reduced cake moisture from 23 to 21%. Addition of 0.4 kg/t of Cu^{2+} ions increased cake thickness from 4 to 6 mm with no adverse effects on cake moisture. Use of 0.2 kg/t of Al^{3+} ions produced a 6.5 mm thick filter cake containing about 25% moisture. Addition of anionic and non-ionic surfactants up to 1.5 kg/t had no significant effects on cake moisture and thickness.

For non-compliance coal use of cationic flocculant at a dosage of 25 g/t increased cake thickness from 5 to 25 mm while cake moisture remained unchanged at 26%. The lowest cake moisture (22.5%) was achieved with a 10 mm thick cake at a dosage of 5 g/t of cationic flocculant. Use of anionic flocculant at a dosage of 10 g/t increased the cake thickness from 4 to 22 mm and cake moisture from 26.5 to 28.5%. Addition of 0.5 kg/t of Al^{3+} ions lowered cake moisture from 25.5 to 21% and increased cake thickness from 5 to 7.5 mm. Addition of anionic and non-ionic surfactants showed only marginal effects on filter cake of the non-compliance coal.

The results obtained from POC testing clearly show that increasing flocculant dosage increased throughput and in most cases decreased cake moisture. For the non-compliance coal, the addition of anionic flocculant reduced cake moisture while the addition of cationic flocculant increased moisture, however both flocculants increased throughput. The most substantial increase in throughput for the non-compliance coal occurred at an anionic flocculant dosage of 15 g/t which increased throughput from a baseline of 24.5 $lb/ft^2/hr$ to 47 $lb/ft^2/hr$. This doubling of throughput was achieved while lowering the cake moisture from 27.9% to 25.7%. The addition of 15 gpt cationic flocculant increased throughput from 20 $lb/ft^2/hr$ to 31 $lb/ft^2/hr$, however cake moisture increased from 25% to 26.1%. These results show that the anionic flocculant was clearly more effective for increasing throughput while reducing cake moisture for the non-compliance coal.

For the compliance coal, a dosage of 15 g/t anionic flocculant was effective for increasing throughput from 14.8 $lb/ft^2/hr$ to 24 $lb/ft^2/hr$ while cake moisture remained unchanged at 27%. A dosage of 15 gpt cationic flocculant increased throughput slightly from 18.2 $lb/ft^2/hr$ to 21.3 $lb/ft^2/hr$, however cake moisture was reduced from 24 to 21.3% over this dosage range.

For metal salt testing, $AlCl_3$ was the most effective for reducing cake moisture at low dosage (<200 mg/kg) for both the high sulfur and compliance coals. The compliance coal was reduced from 27.9 to 26.6% moisture while the high sulfur coal was reduced from 26.5% to 25.5% moisture. At a dosage of 500 mg/kg, $CuCl_2$ was the most effective for both substrates. The compliance coal was reduced to 26.2% moisture while the non-compliance coal was reduced to 24.8% moisture. At this dosage, throughput increases were the most significant when $CuCl_2$ was used for both substrates. For the compliance coal, throughput increased from a baseline of 25 $lb/ft^2/hr$ to 30.5 $lb/ft^2/hr$ while moisture was reduced from 27.9% to 26.2% at a dosage of 500 mg/kg $CuCl_2$. For the non-compliance coal, the same dosage of $CuCl_2$ doubled throughput from a baseline of 18 $lb/ft^2/hr$ to 36 $lb/ft^2/hr$ while reducing cake moisture from 27% to 24.8%.

INTRODUCTION

For cleaning of coal finer than 0.5 mm (28 mesh) processes based on surface chemical technique such as froth flotation and oil agglomeration are the most effective. However, froth flotation process, which is commercially used, produces a product containing 80% moisture. Recently developed column flotation technique, which provides higher recovery of low ash product, also suffers from the same problem of high moisture product. Dewatering of the fine coal to a low (~20%) moisture level using conventional filtration equipment has not been possible. This project offers a novel surface-modification approach to modify coal surface so it could dewater to a low moisture level using conventional and advanced dewatering equipment. The surface modification approach has provided significant reduction in filter cake moisture in laboratory studies at University of Kentucky Center for Applied Energy Research.

The aim of this program is to test the UKCAER-developed novel coal surface modification approach on a pilot scale at the rate of 1-2 tph of solids using vacuum, centrifuge and hyperbaric filtration technique. This proof-of-concept testing is being performed at the Powell Mountain Coal Company Mayflower Plant located in St. Charles, Virginia.

The project involves a teaming arrangement between the University of Kentucky for Applied Energy Research (CAER), the Powell Mountain Coal Company (PMCC), and the Andritz Ruthner Inc. (ARI). The project will extend for a period of 36 months.

APPROACH

A team of scientists and engineers from the Center for Applied Energy Research, Powell Mountain Coal Company, and Andritz Ruthner Inc. has been formed to accomplish the objectives of the program. Each team member brings fine particle dewatering knowledge and experience to the project. The UKCAER, who is the prime contractor, will manage the project and will conduct the major part of the study. The PMCC will provide assistance and facility in conducting the pilot scale tests, and ARI will conduct laboratory dewatering tests and also pilot scale tests using the hyperbaric pressure filtration unit at the PMCC. Figure 1 shows the project organization chart. The project schedule for the first two years of the program is shown in Figure 2.

The CAER collected clean coal froth samples from the Mayflower plant for the laboratory studies. Samples of clean coal slurries were also sent to ARI for studies using their laboratory scale hyperbaric unit. At both organizations, emphasis will be given to identify optimum process and operating conditions using vacuum and pressure techniques to dewater the clean coal slurry to about 20% level moisture. It is believed that the proposed research can achieve low moisture product on a pilot scale to the same extent which has already been achieved in laboratory studies.

The basic components of the process has been tested in laboratory. The purpose of the proposed work here is to evaluate all of the component steps on a consistent basis, and, to the extent possible in laboratory studies, demonstrate the feasibility of their integration. The outcome of this program will be to identify a process/technique combination which is able to achieve a 20% or lower moisture in the fine clean coal product and to provide technical and economic

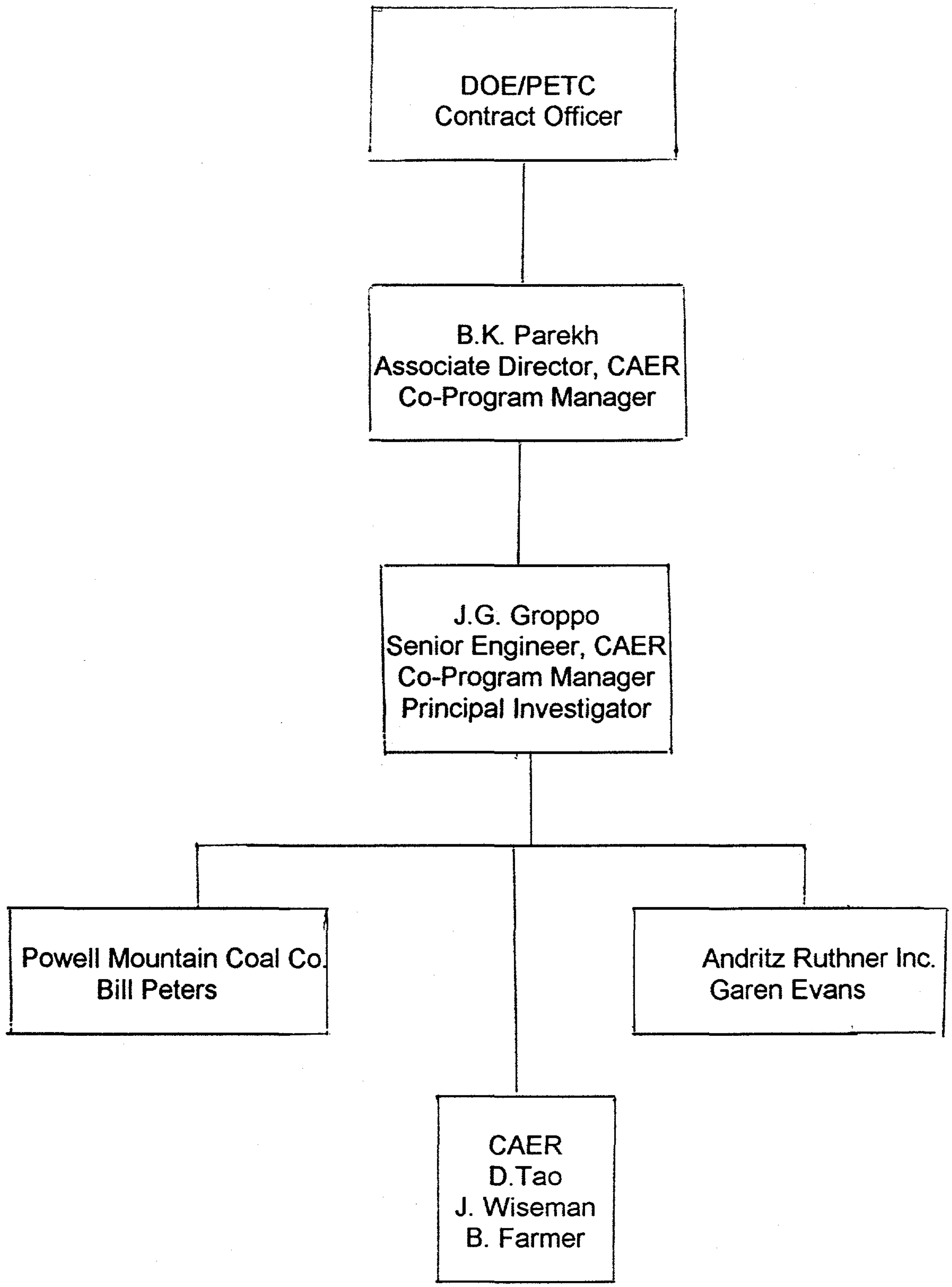

Figure 1. Project management organization chart

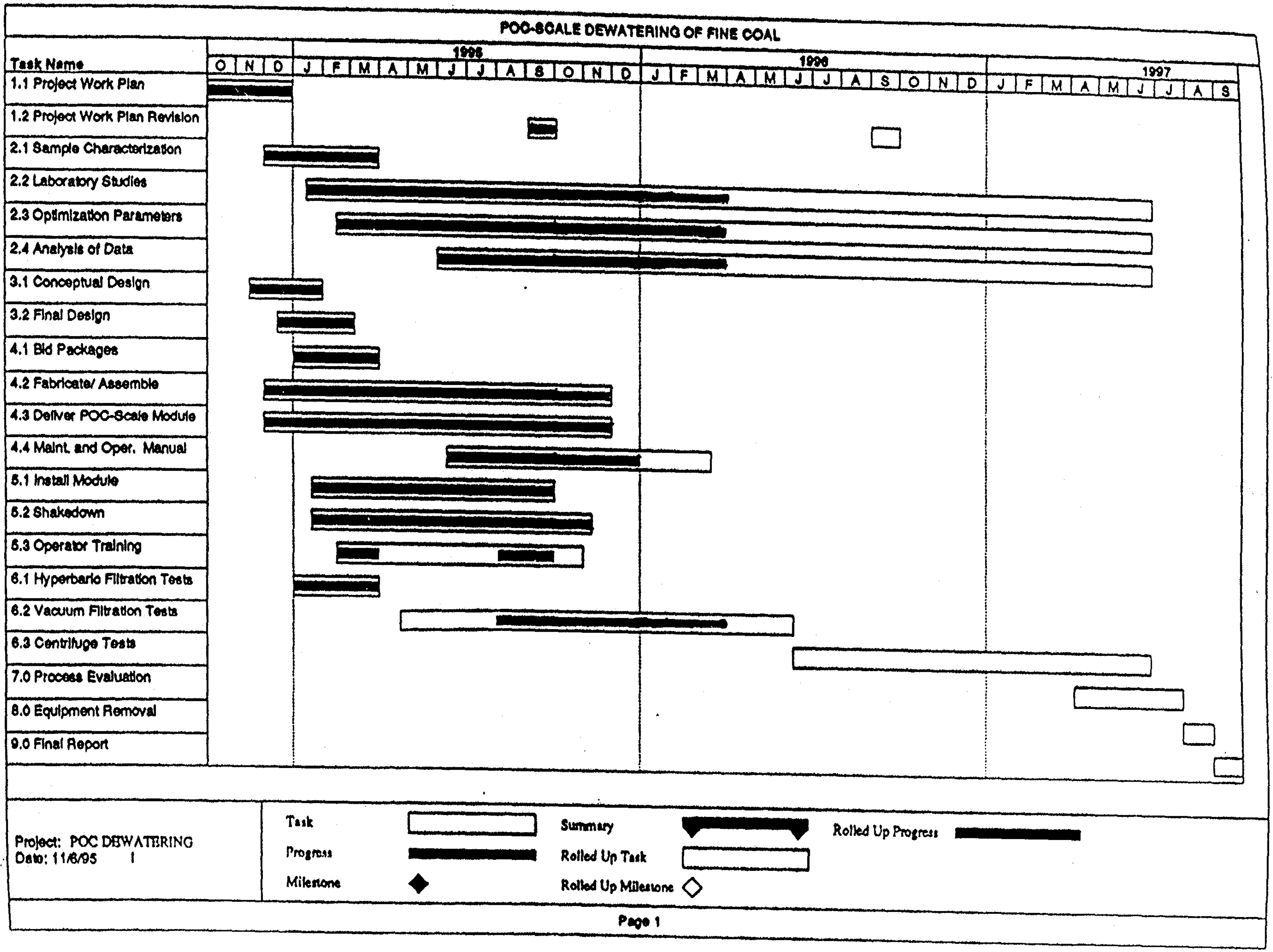

Figure 2. Up-to-date project schedule

evaluation of the integrated concept in sufficient detail for a coal company to decide to install the dewatering process in their plant.

ACCOMPLISHMENTS DURING THE QUARTER

The project has been divided into tasks and subtasks listed in Table 1. Each task and subtask has specific objective which can be inferred from its title. During this quarter (January 1 to March 31, 1996) work was done on Tasks 2 and 5.

Task 2. Sample Analysis and Laboratory Testing:

The laboratory dewatering tests were conducted using both compliance (low sulfur) and non-compliance (high sulfur) clean coal slurries obtained from the Powell Mountain Coal Co. The particle size distribution and other properties of both coal slurries have been presented in the previous quarterly progress reports.

Vacuum Dewatering

During the past quarter intensive laboratory studies were conducted on vacuum dewatering of both compliance and non-compliance coal. The objective of this work is to develop new approach for enhancing dewatering of fine coal slurry by vacuum filtration and provide guidelines for pilot-scale testing of these processes. The objective was achieved by investigating the effects of various reagents on vacuum dewatering performance of both coals under various operating conditions. The reagents used in this work are believed to enhance

Table I. Outline of Work Breakdown Structure

Task 1.	Project Work Planning	
	Subtask 1.1	Project Work Plan
	Subtask 1.2	Project Work Plan Revisions
Task 2.	Samples Analysis and Laboratory Testing	
	Subtask 2.1	Acquisition and Characterization of Samples
	Subtask 2.2	Laboratory Scale Testing
	Subtask 2.3	Optimization of Parameters
	Subtask 2.4	Analysis of Data
Task 3.	Engineering Design	
	Subtask 3.1	Conceptual Design Package
	Subtask 3.2	Final Design Package
	Subtask 3.3	Construction Schedule
Task 4.	Procurement and Fabrication	
	Subtask 4.1	Bid Packages
	Subtask 4.2	Fabricate/Assemble Components
	Subtask 4.3	Deliver POC-Scale Module and Install
	Subtask 4.4	Maintenance and Operating Manual
Task 5.	Installation and Shakedown	
	Subtask 5.1	Install and Tie-in Module
	Subtask 5.2	Startup Procedures/Shakedown
	Subtask 5.3	Operators Training
Task 6.	System Operation	
	Subtask 6.1	Test Coal No. 1
	Subtask 6.2	Test Coal No. 2
Task 7.	Process Evaluation	
Task 8.	Equipment Removal	
Task 9.	Reporting	
	Subtask 9.1	Monthly Reports
	Subtask 9.2	Project Final Report

coal dewatering by modifying the coal surface to provide favorable dewatering characteristics such as:

- high hydrophobicity
- low surface tension
- large aggregate size
- high permeability of filter cake, etc.

Reagents that have been studied in the past quarter include flocculants (anionic Procol 156 and cationic Procol 371), surfactants (sodium 2-ethylhexyl sulfate and octyl phenoxy polyethoxy ethanol), and metal ions (Al^{3+} and Cu^{2+}). The results are shown and discussed under the following subtitles.

Experimental system

The vacuum dewatering tests were initially performed with a filter-leaf setup shown in the fifth quarterly report, with a beaker being used as the filter bowl that was stirred by a magnetic bar. It simulates the industrial vacuum filter system and offers the advantage of forming filter cake without segregation of large and small particles. However, it was found that the dewatering results from this system were dependent on the stirring speed of magnetic stirrer which is difficult to quantify, as shown in Figure 3. The stirring speed is represented in the figure by the scale number on the stirrer (larger number represents faster speed). The cake thickness increased initially with stirring speed and decreased after it reached the maximum at about 3 while cake moisture increased consistently. At low stirring speed coal particles tends to settle down: at high

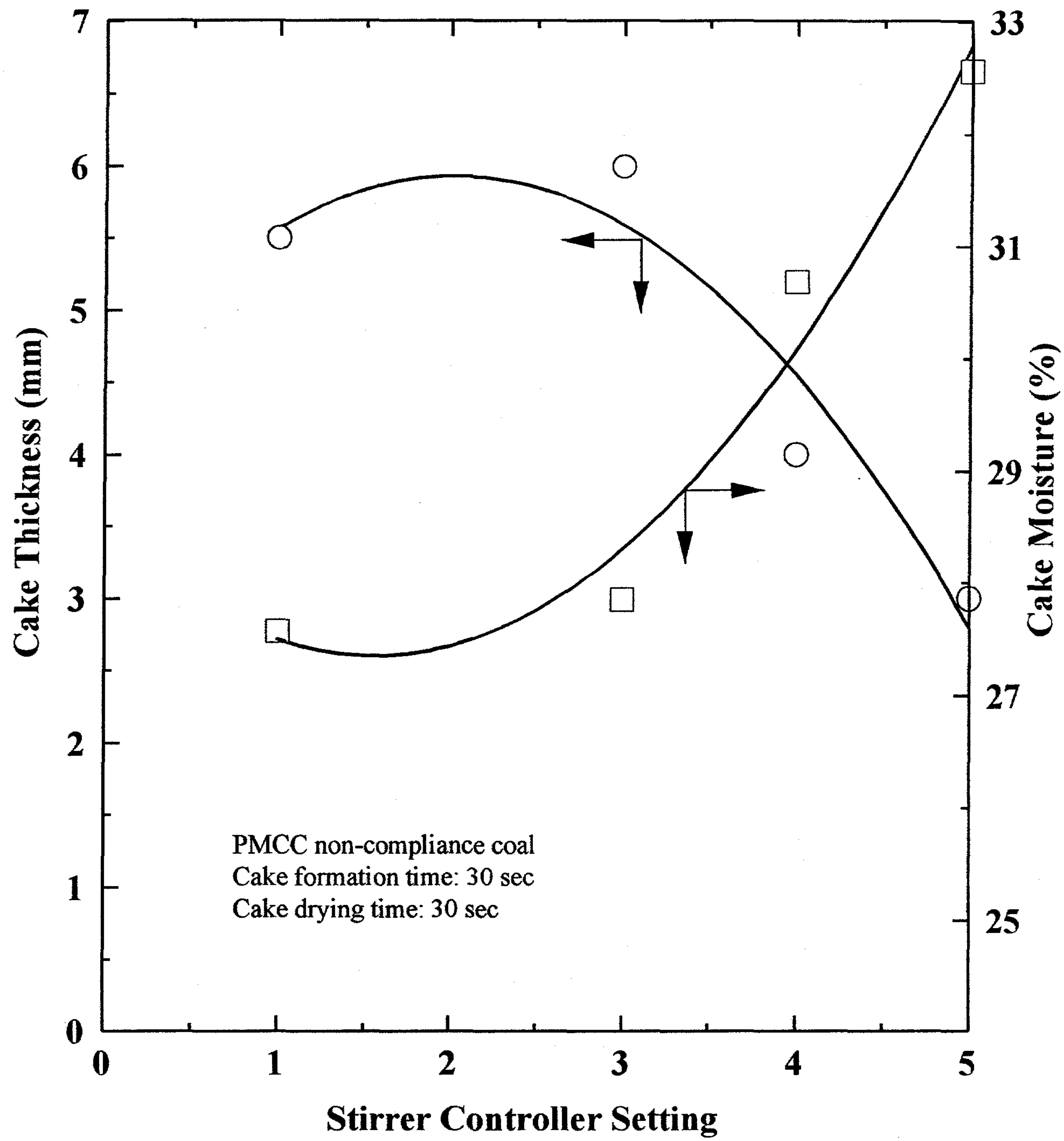

Figure 3. Effect of stirring speed of filter cell on cake thickness and moisture.

speed particles may be thrown toward the wall of the beaker. Apparently the stirring speed is critical for this system and has to be maintained at an appropriate value to keep solids from settling or being thrown away from the center.

In order to overcome these drawbacks, a modified vacuum dewatering system was used in the present study. As shown in Figure 4, a rectangular cell rather than a beaker was employed as the filter bowl to minimize vortex created by circular stirring. In addition, slurry was circulated in the new system by incorporating a pump in the circuit, which is a common practice in industrial applications. This system was tested extensively under various operating conditions and data generated with this system were reproducible and operator-independent.

Unless otherwise specified, all tests were conducted under a vacuum of 25-in Hg at pH 8.1 for compliance coal and pH 7.1 for non-compliance coal. The slurry was conditioned with reagent(s) for 5 minutes before filter leaf was submerged in the filter cell.

Baseline tests

Initial baseline dewatering tests were conducted using no reagents with compliance and non-compliance coals under varying cake formation and drying time. The results were used to determine appropriate operating conditions for evaluating the effectiveness of different reagents for dewatering.

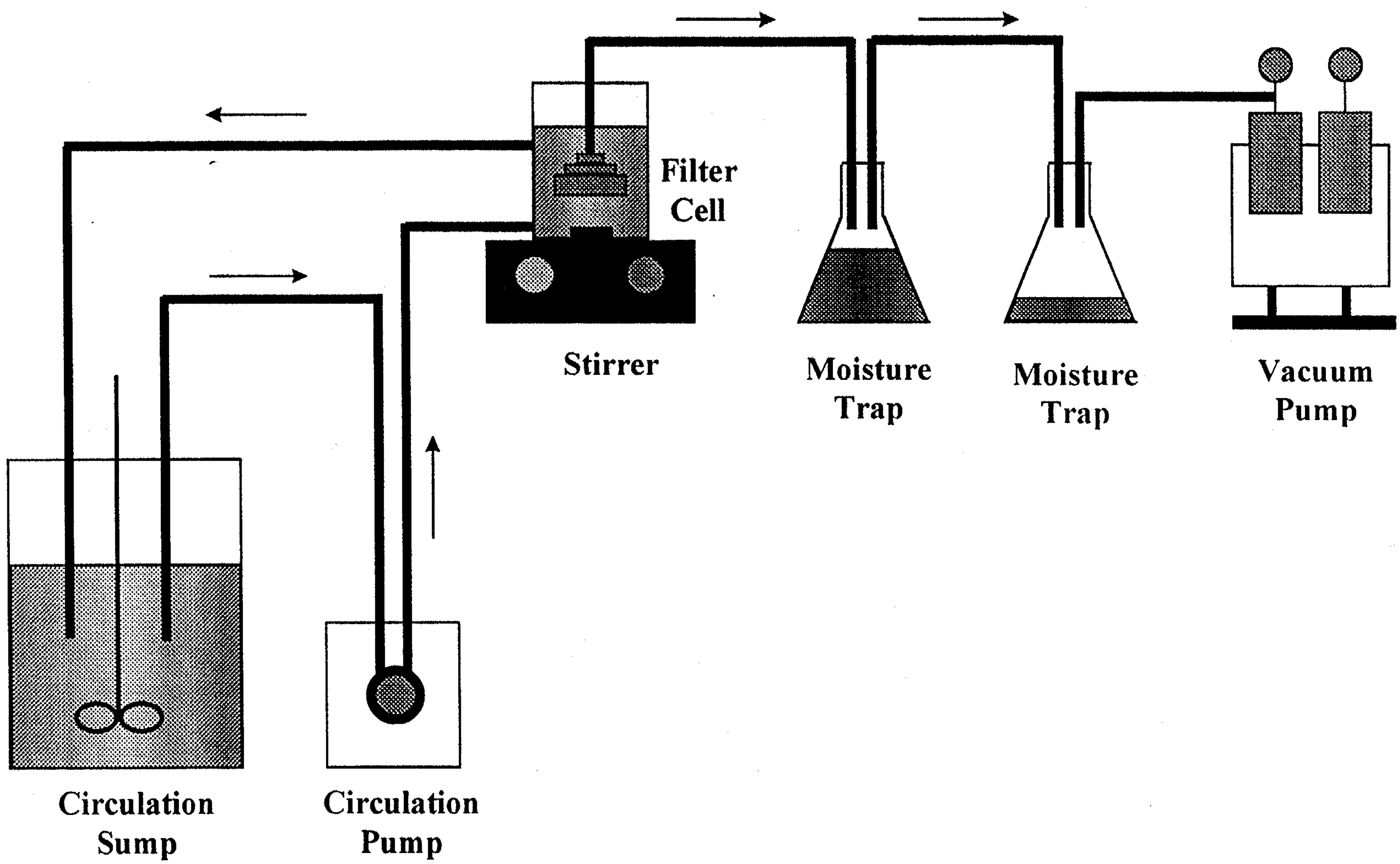

Figure 4. Illustration of experimental set-up for coal vacuum filtration.

Figure 5 shows the effect of cake formation time on cake thickness and moisture at a cake drying time of 40 seconds with the compliance coal. Both cake thickness and moisture were almost linearly dependent on the cake formation time. This indicates that longer cake formation time recovered more solids from slurry, resulting in a thicker filter cake which was, however, higher in moisture.

Figure 6 shows cake thickness and moisture as a function of cake drying time at a constant cake formation time of 30 seconds. The cake thickness was determined by the cake formation time and was independent of the cake drying time. The cake moisture decreased, as expected, with cake drying time but only marginal changes were observed in Figure 6. It appeared difficult to reduce cake moisture significantly by using longer cake drying time, possibly because of fine particle size of this coal (D_{50} = 29.5 μm). This highlights the necessity of developing new approaches to enhanced dewatering.

Figures 7 and 8 show cake thickness and cake moisture as a function of cake formation time and cake drying time, respectively, for the PMCC non-compliance coal slurry. Longer cake formation time gave rise to thicker but wetter cake, which was also observed in Figure 5 with the compliance coal. However, the filter cake moisture decreased with increasing cake drying time (Figure 8), indicating noncompliance coal was more readily dewatered than compliance coal. This is possibly due to the fact that non-compliance coal contains coarser particles (D_{50} = 37.3 μm).

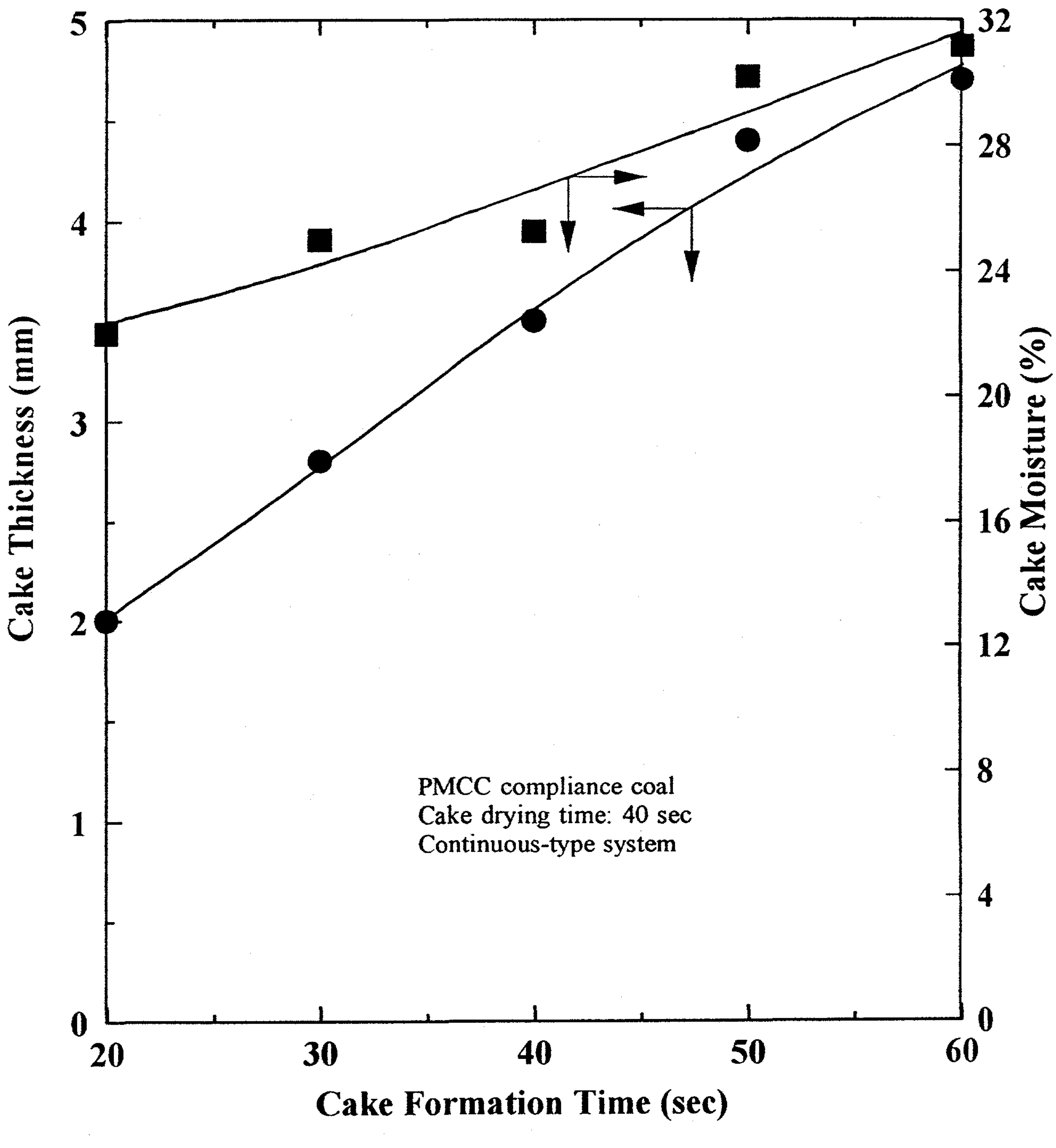

Figure 5. Effect of cake formation time on cake thickness and moisture with compliance coal.

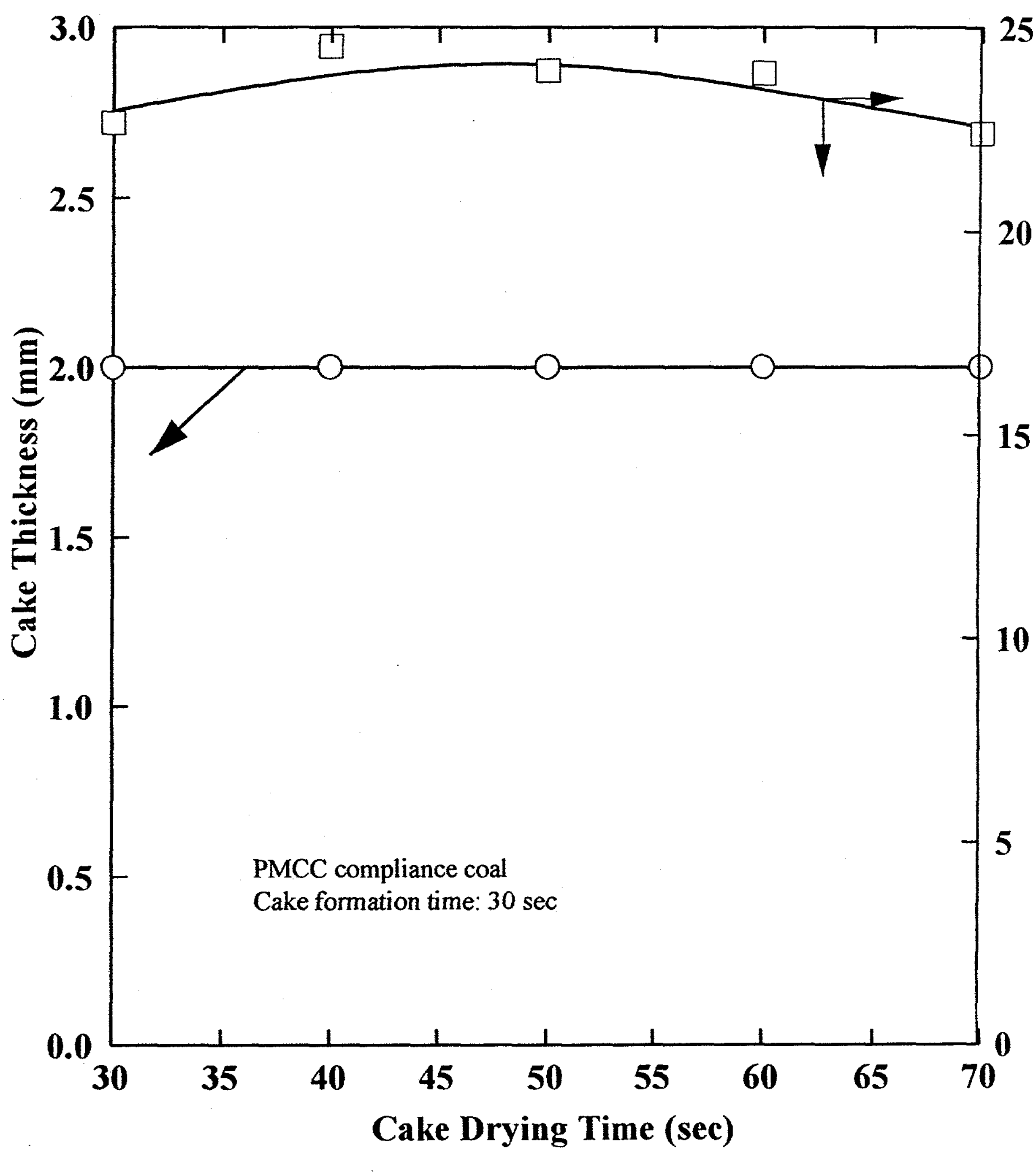

Figure 6. Effect of cake drying time on cake thickness and moisture with compliance coal.

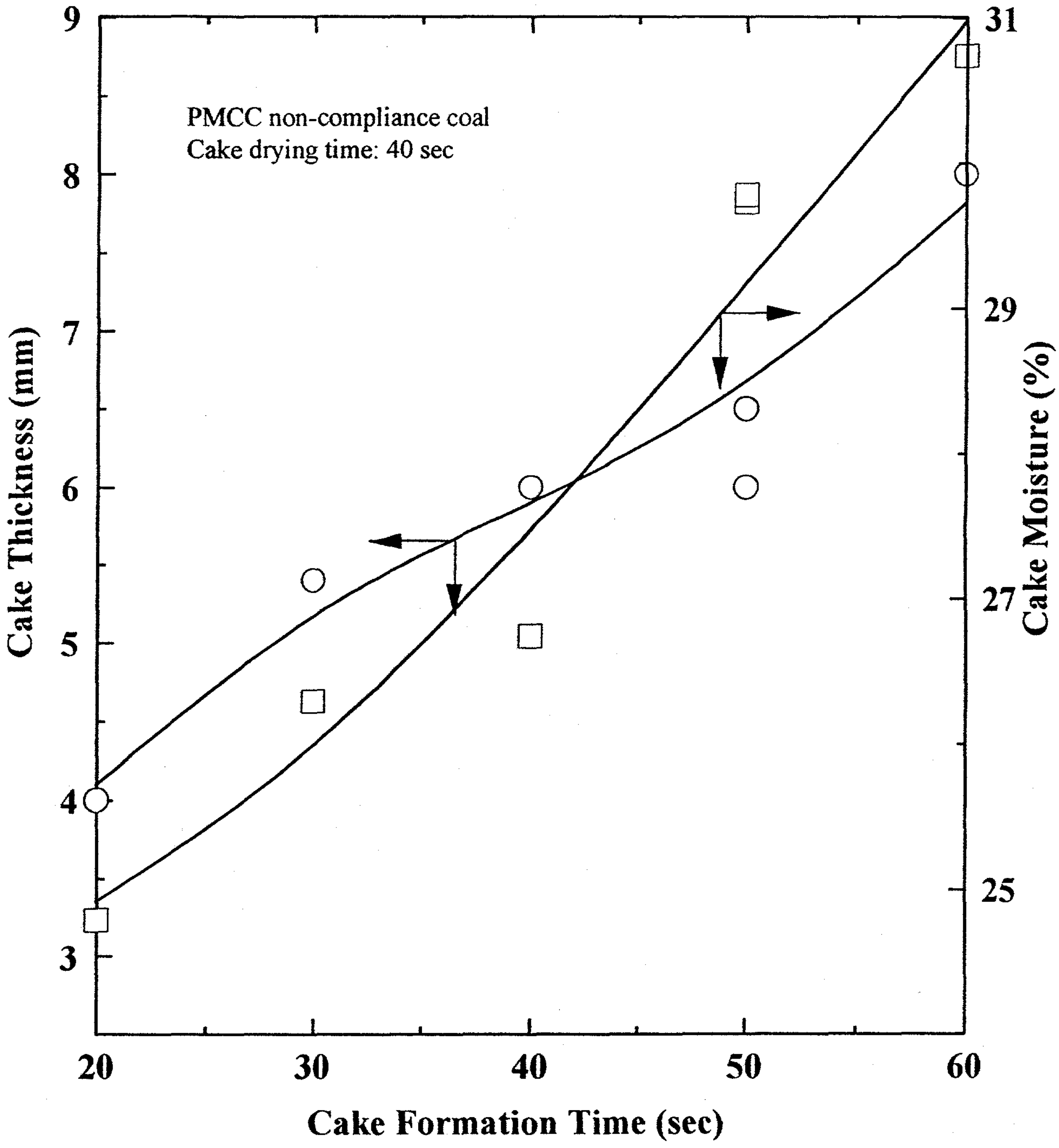

Figure 7. Effect of cake formation time on cake thickness and moisture with non-compliance coal.

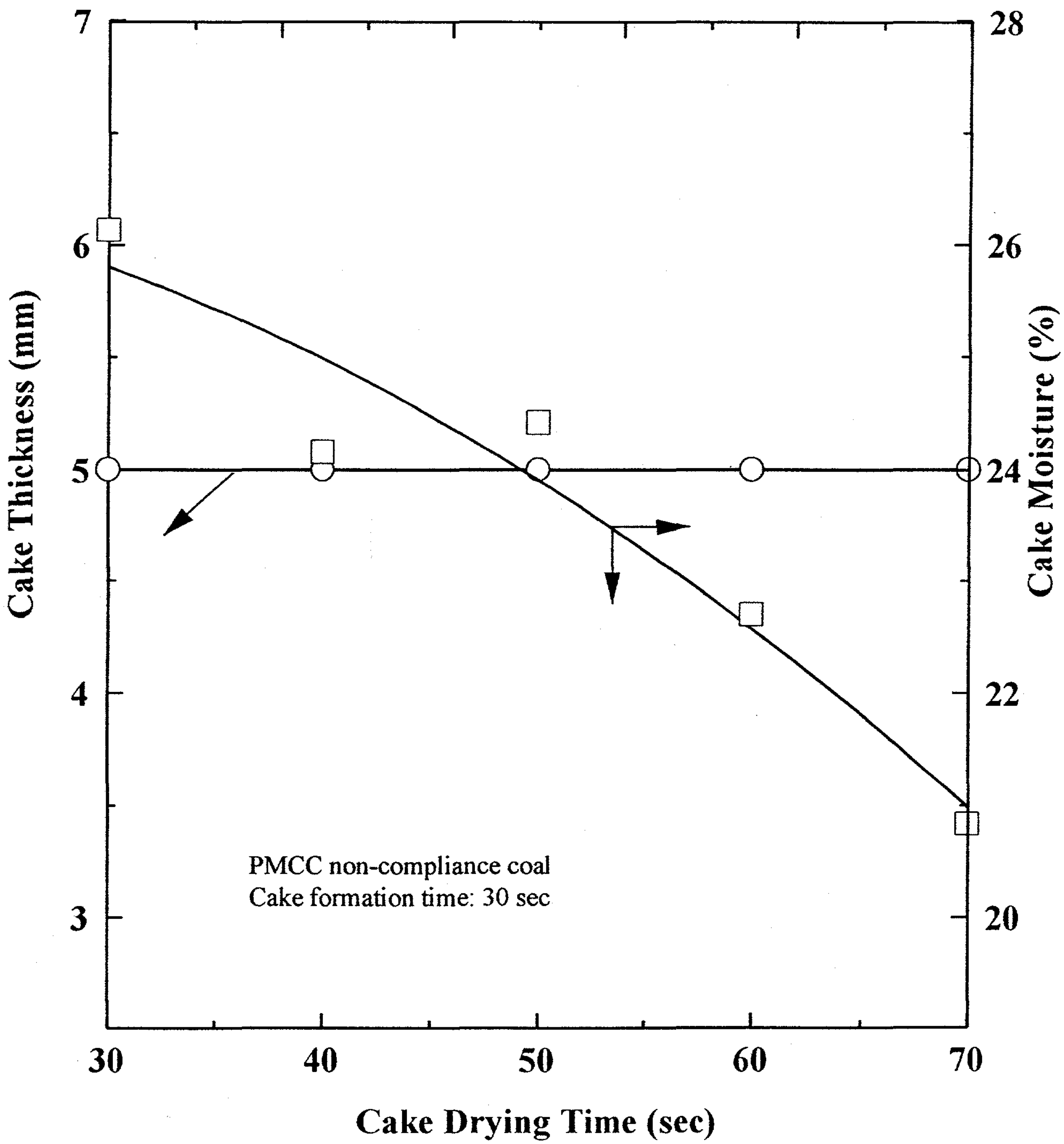

Figure 8. Effect of cake drying time on cake thickness and moisture with non-compliance coal.

Addition of Flocculant

Both anionic (Procol 156) and cationic (Procol 371) flocculants, supplied by Allied Colloids, were studied for their effects on coal dewatering. Figure 9 shows the dependence of cake thickness and cake moisture on the dosage of cationic flocculant with the compliance coal slurry. As the flocculant dosage increased from 0 to 25 g/t, cake thickness increased from about 3 to 9 mm while cake moisture increased from 23 to 27%. By contrast, cake moisture increased from 23 to 32% with increasing cake thickness from 2 to 4.7 mm in the absence of flocculant, as shown in Figure 5. Obviously, the moisture increase with cake thickness was much less significant in the presence of cationic flocculant than in its absence. In other words, a lower moisture filter cake can be obtained at a given cake thickness by use of flocculant. This is primarily because the use of flocculants produced flocs that are considerably larger than individual coal particles.

Figure 10 shows effects of anionic flocculant on cake thickness and cake moisture with compliance coal. The cake thickness increased from 4 to 10 mm with increasing the dosage of flocculant from 0 to 10 g/t and then leveled off. The cake moisture, on the other hand, was nearly independent of the flocculant dosage.

Figure 11 shows the effect of cationic flocculant dosage on cake thickness and cake moisture for the non-compliance coal. As the dosage of cationic flocculant increased, cake moisture decreased initially from 26 to about

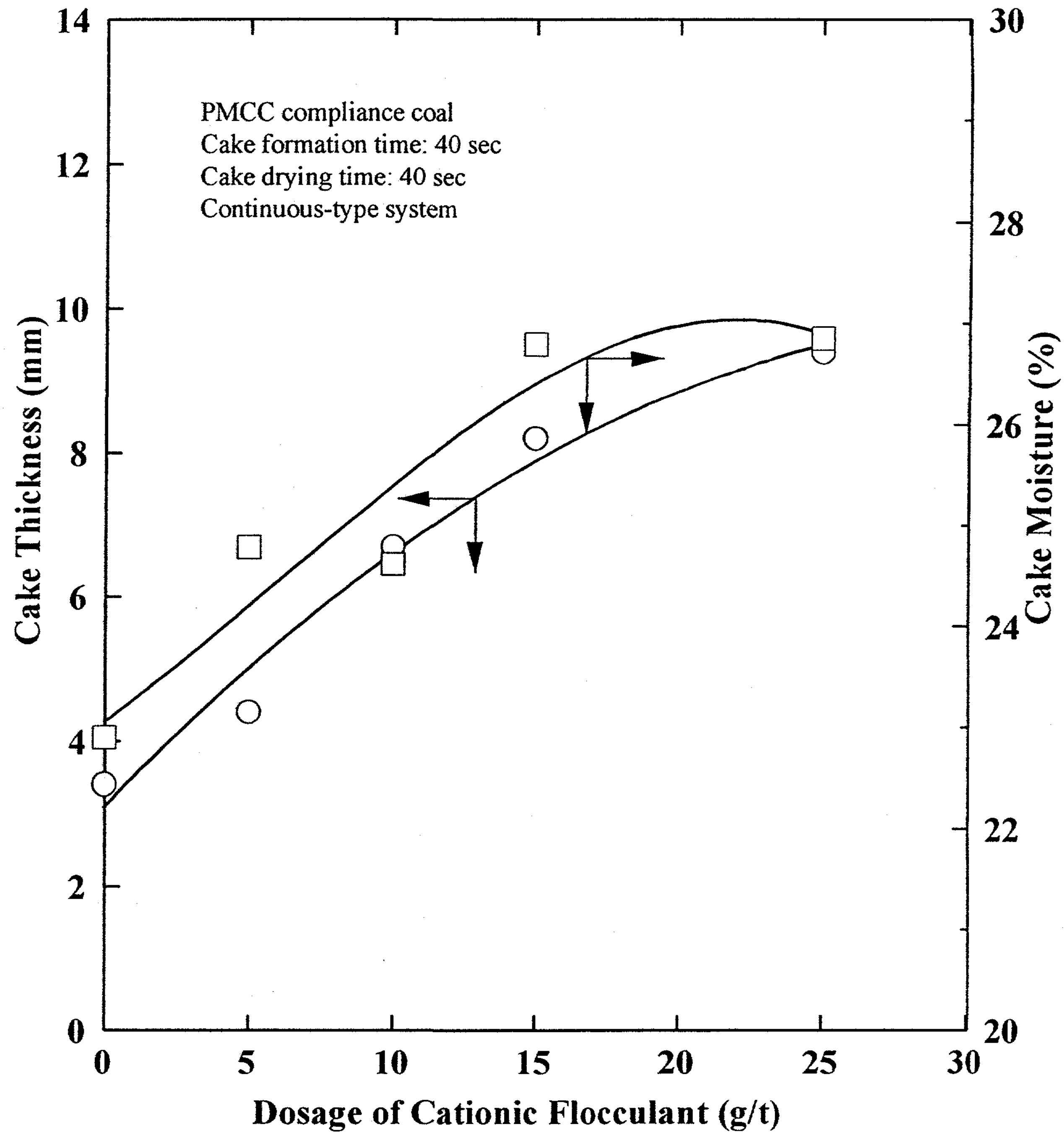

Figure 9. Effect of cationic flocculant dosage on cake thickness and moisture with compliance coal.

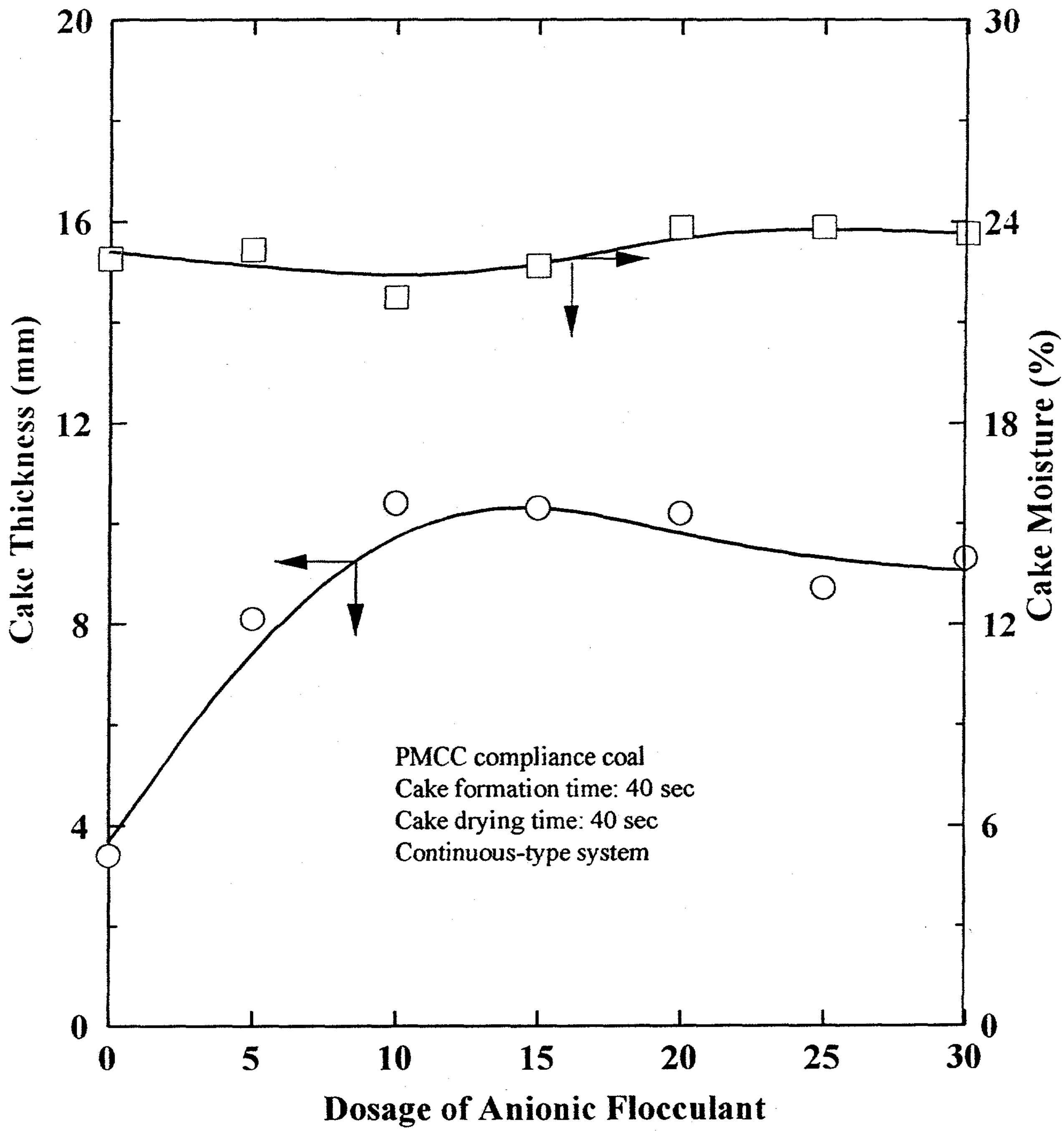

Figure 10. Effect of anionic flocculant dosage on cake thickness and moisture with compliance coal.

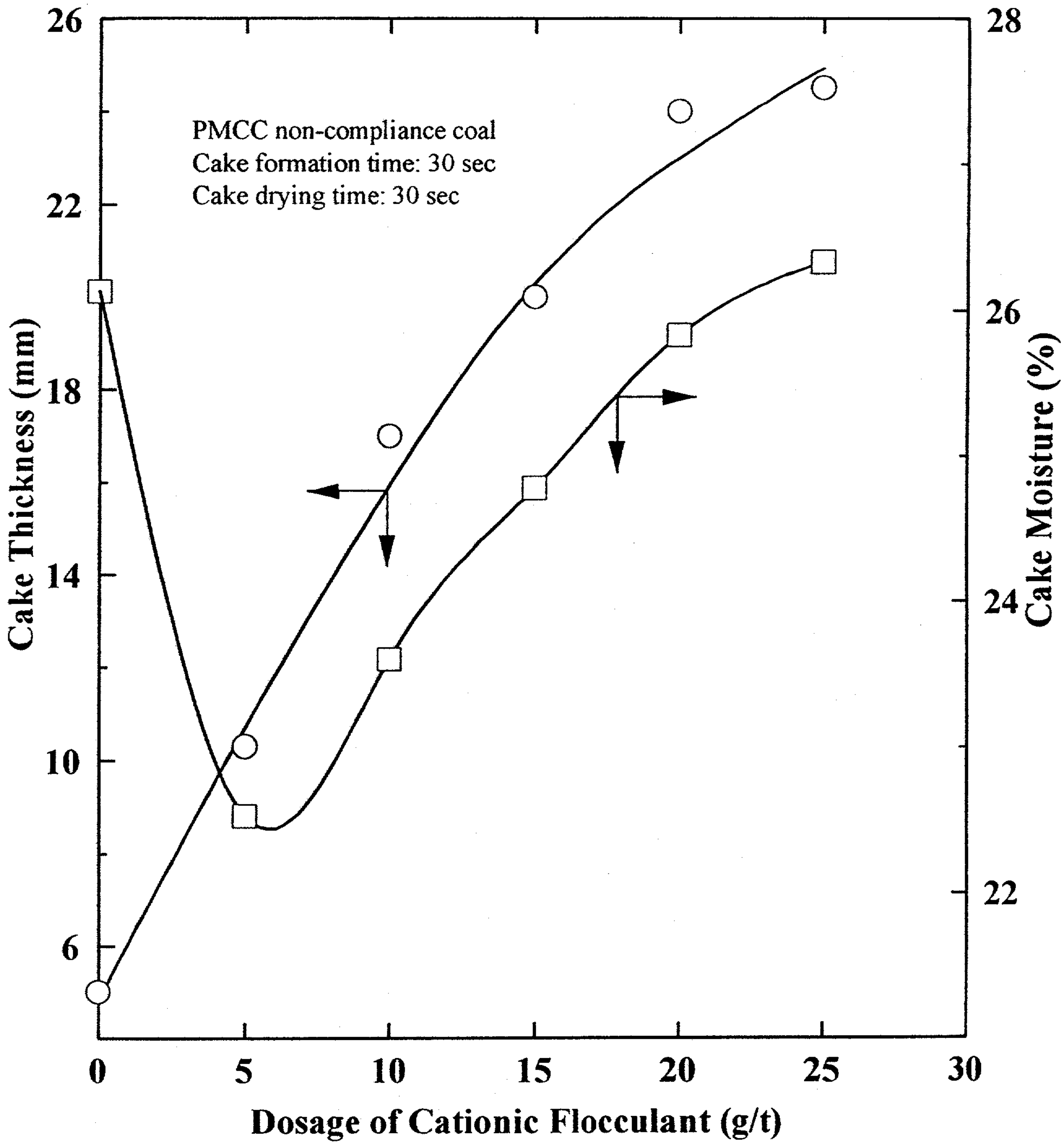

Figure 11. Effect of cationic flocculant dosage on cake thickness and moisture with non-compliance coal.

22.5% and then gradually increased. The cake thickness increased sharply from approximately 5 to 25 mm as the dosage increased from 0 to 25 g/t. The cake moisture at the maximum cake thickness (25 mm) at 25 g/t flocculant was approximately the same as a 3 mm thick filter cake in the absence of flocculant.

Figure 12 shows effects of anionic flocculant on cake thickness and cake moisture with non-compliance coal. Increasing the dosage of the anionic flocculant to 15 g/t increased cake thickness from 4 to 22 mm. However, dosages higher than 15 g/t did not further increase cake thickness. The filter cake moisture shows an increase of about 2% over the entire range of anionic flocculant dosage.

Effect of Surfactant

Figures 13 and 14 show effects of anionic surfactant dosage on filter cake thickness and moisture with the compliance and non-compliance coal, respectively. Use of anionic surfactant at a dosage of up to 1.5 kg/t increased cake thickness by approximately 1 mm for both coals. With compliance coal cake moisture increased from 24 to 27% as the dosage increased from 0 to 0.6 kg/t and reduced back to 25% as the dosage further increased to 1.5 kg/t. With non-compliance coal cake moisture increased by approximately 2% at all dosages except 0.6 kg/t.

Figures 15 and 16 show effect of non-ionic surfactants dosage for compliance and non-compliance coal, respectively. Figure 15 shows that as the surfactant dosage increased from 0 to 0.9 kg/t with the compliance coal, cake

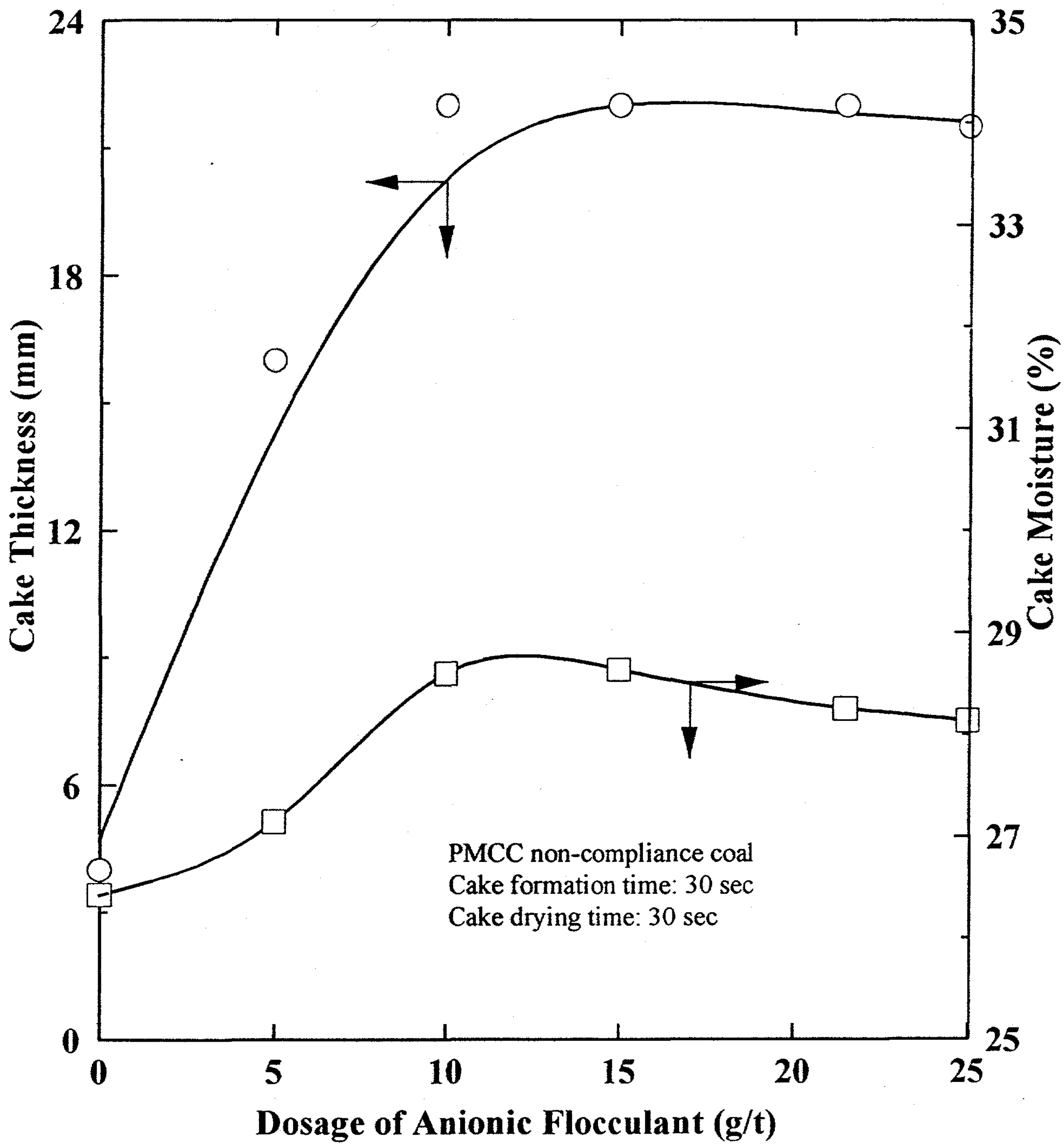

Figure 12. Effect of anionic flocculant dosage on cake thickness and moisture with non-compliance coal.

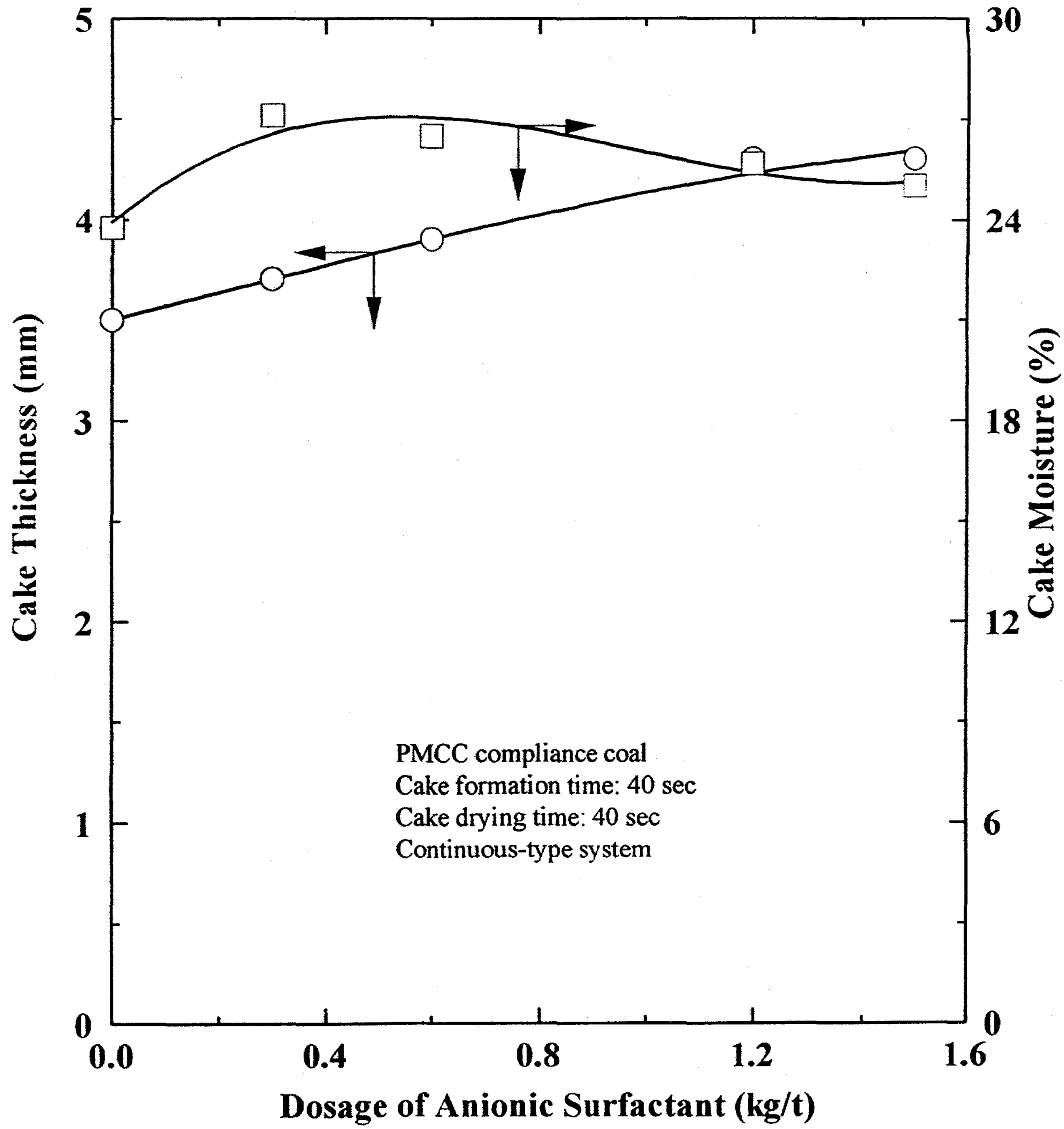

Figure 13. Effect of anionic surfactant dosage on cake thickness and moisture with compliance coal

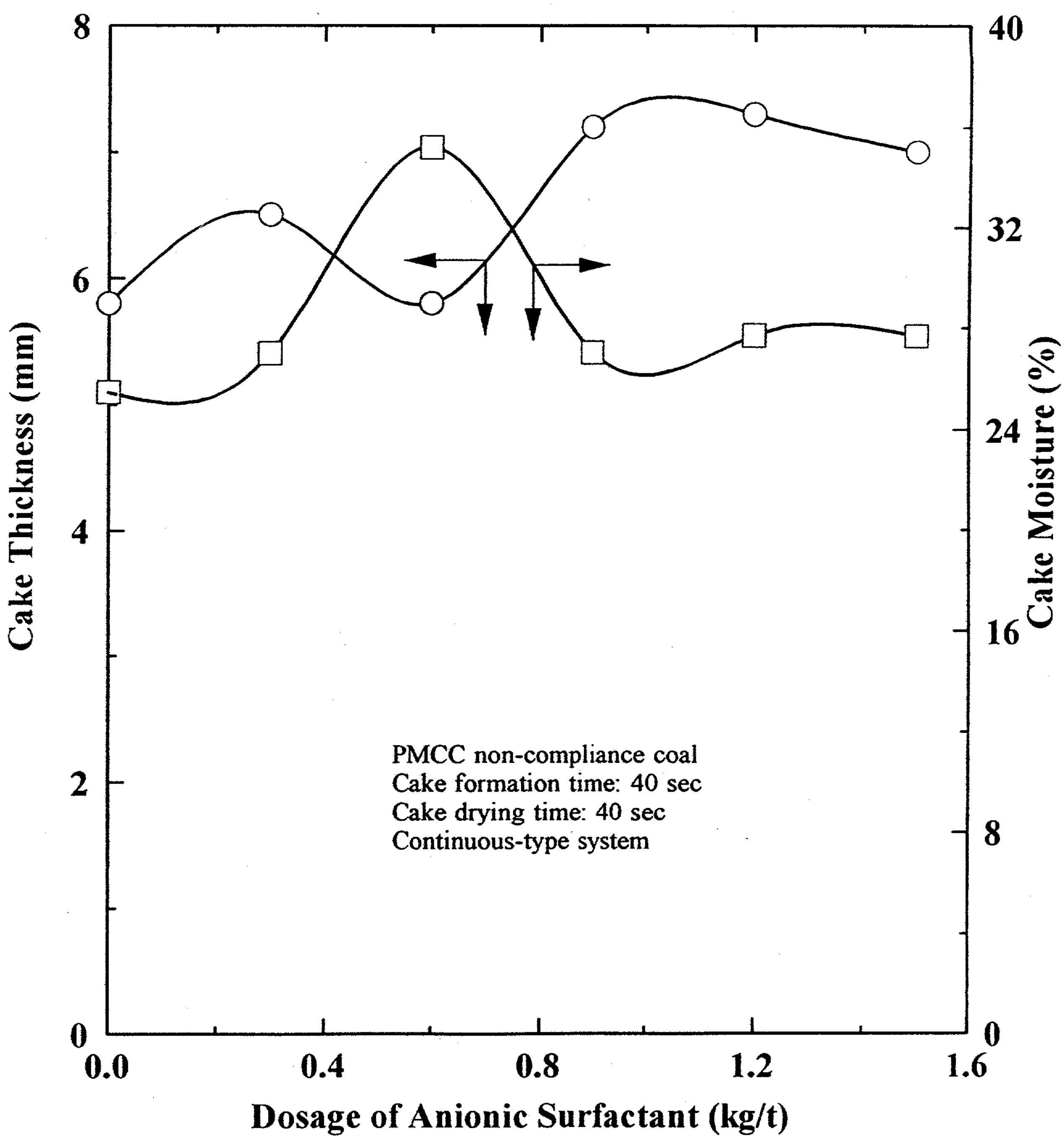

Figure 14. Effect of anionic surfactant dosage on cake thickness and moisture with non-compliance coal.

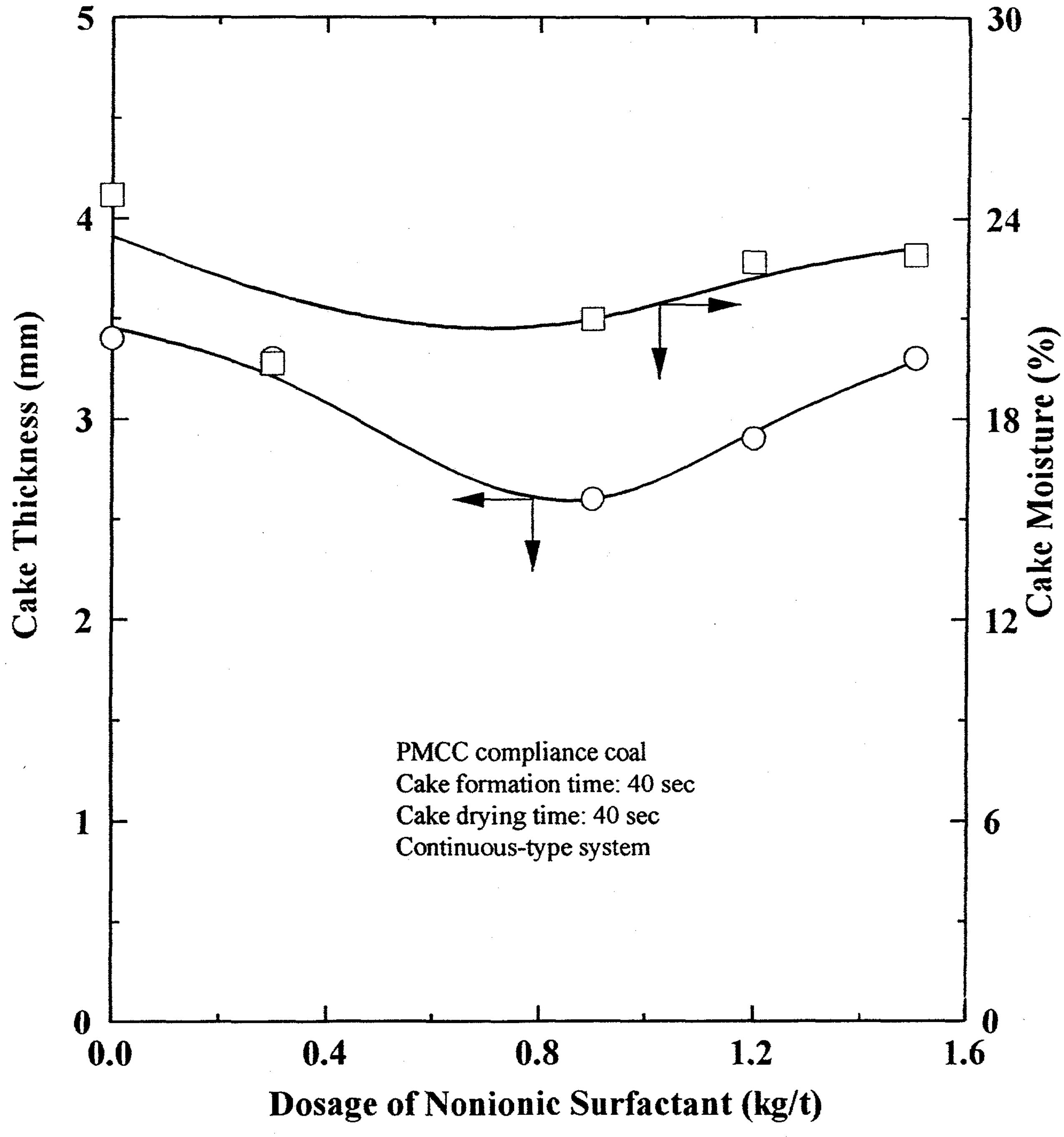

Figure 15. Effect of non-ionic surfactant dosage on cake thickness and moisture with compliance coal.

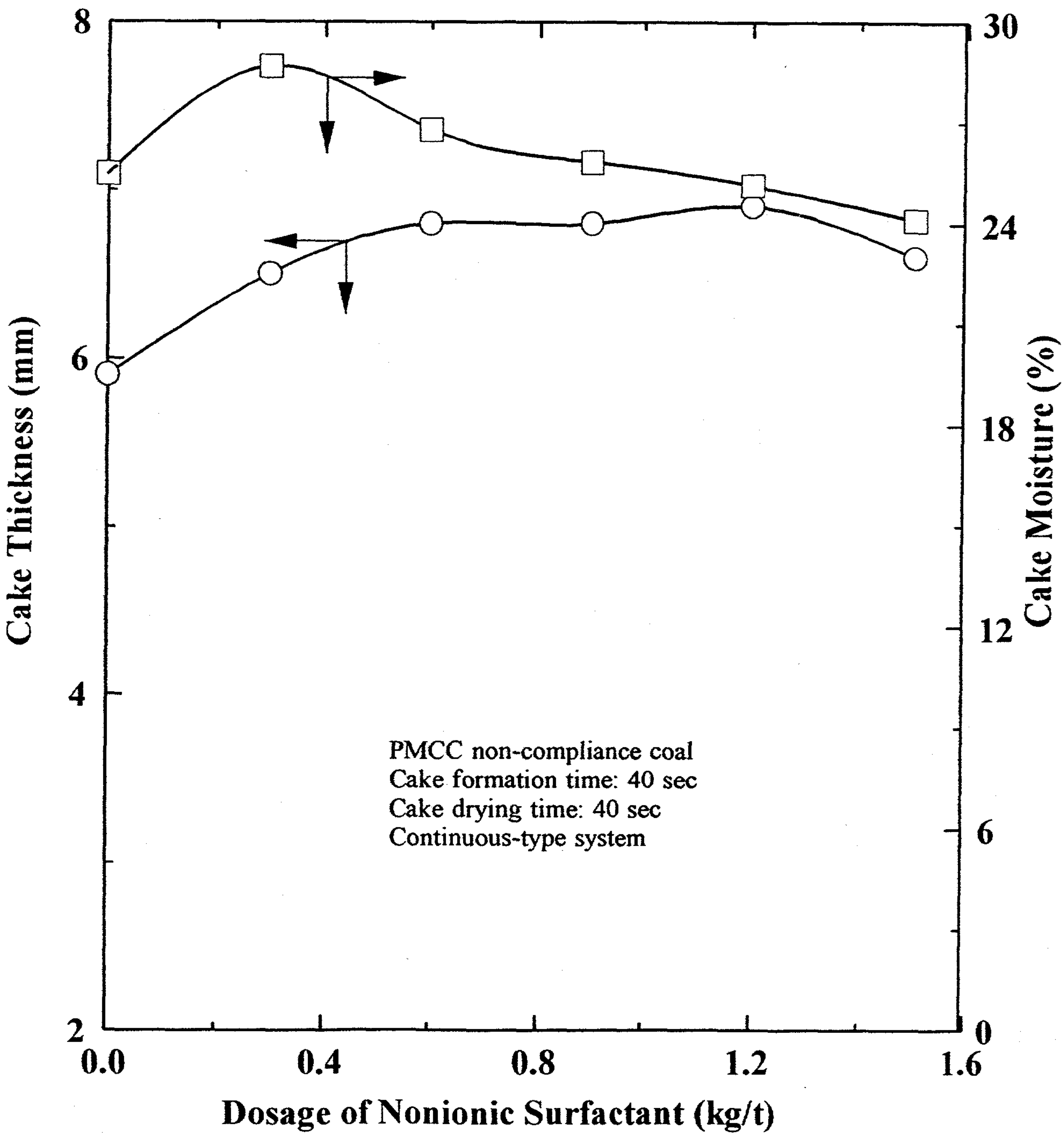

Figure 16. Effect of non-ionic surfactant dosage on cake thickness and moisture with non-compliance coal.

thickness decreased from 3.4 to 2.6 mm and cake moisture also reduced, from 25 to 21%. Further increase in the surfactant dosage to 1.5 kg/t increased cake thickness to 3.3 mm and cake moisture to 23. For the non-compliance coal slurry, the use of non-ionic surfactant increased cake thickness by approximately 1 mm at a dosage of 0.6 kg/t (Figure 16). Dosage higher than 0.6 kg/t did not further increase cake thickness. The use of non-ionic surfactant at a low dosage of 0.3 kg/t, increased, rather than decreased, cake moisture. This was possibly because it produced thicker cake that was more difficult to dewater. As the dosage of non-ionic surfactant increased, the decrease in the surface tension outweighed the increase in cake thickness and as a result, cake moisture decreased. At the dosage of 1.5 kg/t, cake moisture was reduced to 24%. This represents an absolute 1.5% reduction in cake moisture from 25.5% moisture obtained in the absence of surfactant.

It can be summarized that use of surfactants could increase cake thickness and lower cake moisture. However, the effects of surfactants on these two cake parameters can only be considered marginal.

Effect of Metal ion

Figure 17 shows the effects of Cu^{2+} ion addition on cake thickness and moisture at pH 6.5 which is the point-of-zero-charge (PZC) of coal in the presence of Cu^{2+}. The cupric ions were added to slurry in the form of $CuCl_2$. Figure 17 indicates that Cu^{2+} had no significant influence on cake moisture; but it considerably increased cake thickness, presumably due to particle aggregation

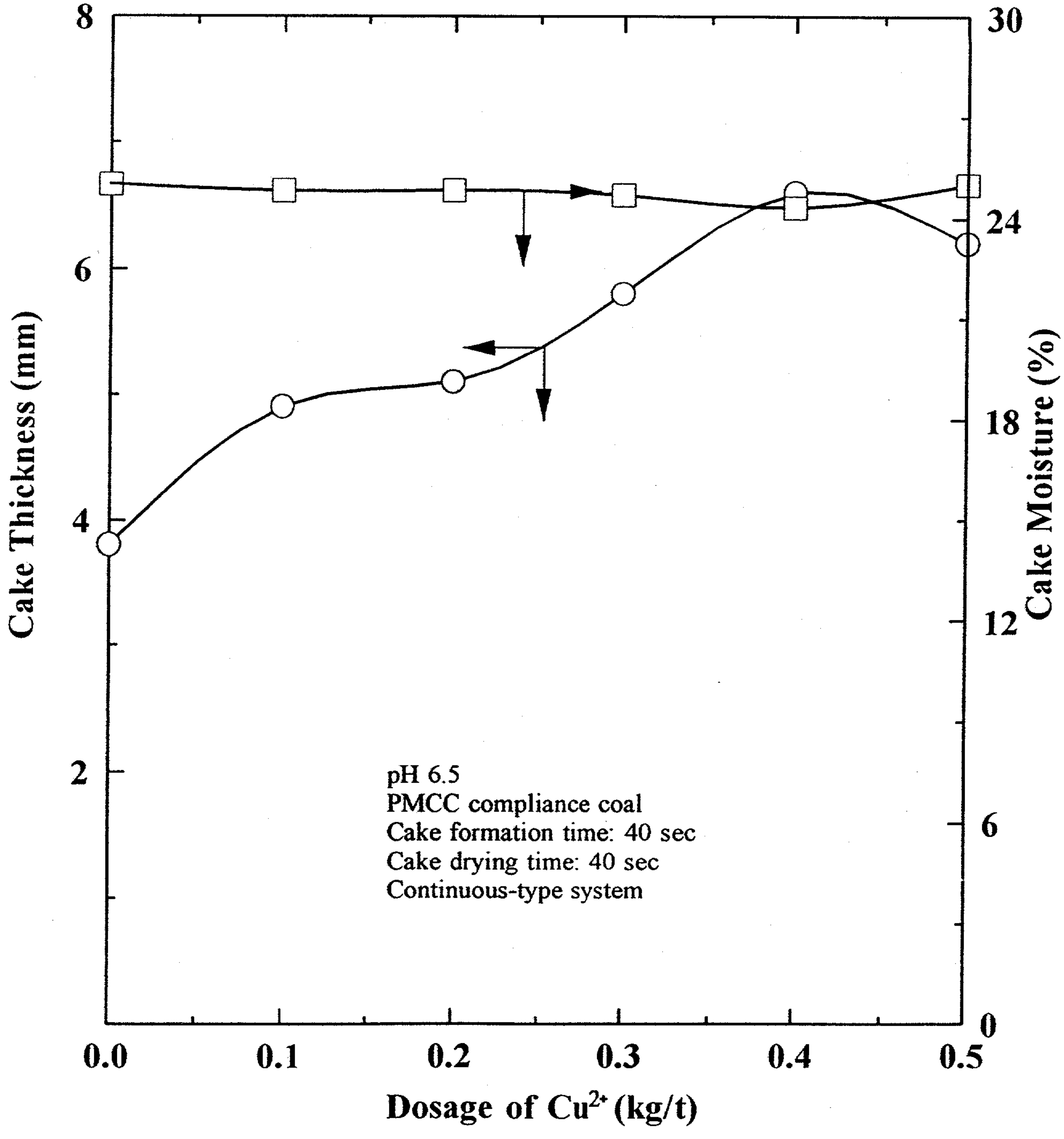

Figure 17. Effect of Cu^{2+} at dosages up to 0.5 kg/t on cake thickness and moisture with compliance coal.

at PZC. An additional test was conducted at an extremely high dosage of Cu^{2+}, i.e., 2.5 kg/t, and results are shown in Figure 18. Increase in both cake thickness and moisture was observed.

Figure 19 Shows the effect of Al^{3+} ion dosage on cake thickness and moisture with the compliance coal at pH 9. The use of Al^{3+} increased cake thickness which leveled off at a dosage of 0.4 kg/t. The cake moisture, however, decreased initially and then increased to approximately 27% at a dosage of 0.5 kg/t compared to the 26% moisture in the absence of Al^{3+} ions. The initial decrease in cake moisture at lower dosages of Al^{3+} was believed to result from the addition of Al^{3+} that generated aggregates which depressed the capillary rise. The increase in cake moisture at higher dosages was associated with increased cake thickness, and possibly surface recharging as well.

Effect of Cu^{2+} ions on dewatering of non-compliance coal at pH 6.5 is shown in Figure 20. Higher dosage of Cu^{2+} ions produced slightly thicker cake. The cake moisture was reduced at dosages lower than 0.3 kg/t and increased at higher dosages. This behavior is similar to that shown in Figure 19 with the compliance coal in the presence of Al^{3+}.

Figure 21 shows effects of Al^{3+} on cake thickness and moisture with the non-compliance coal at pH 9. The use of Al^{3+} increased cake thickness more significantly than Cu^{2+}, due to its higher valence. The cake moisture showed unique dependence on the dosage of Al^{3+}. Increase in Al^{3+} dosage up to 0.25 kg/t did not show significant effects on cake moisture. Cake moisture increased

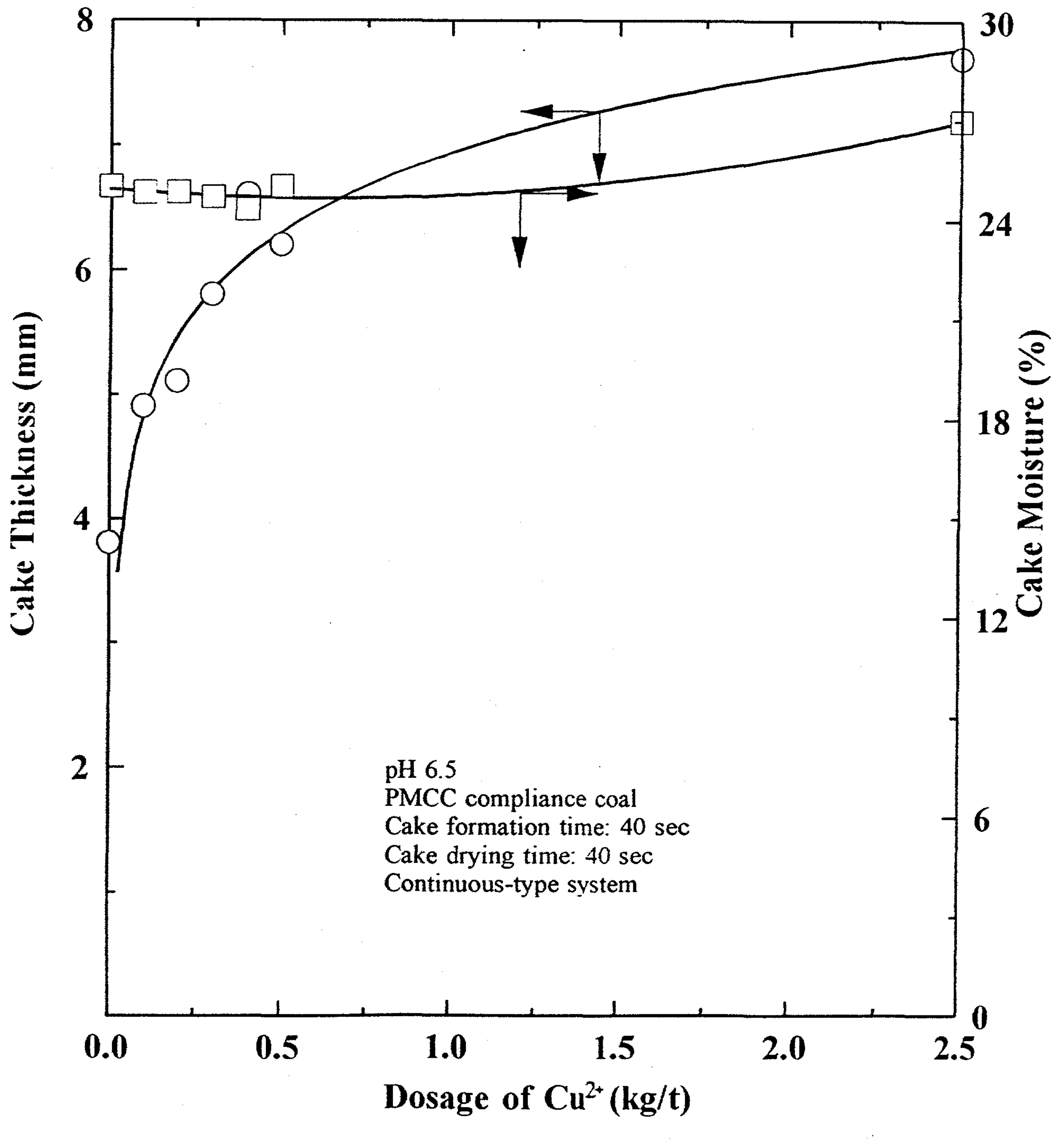

Figure 18. Effect of Cu^{2+} at dosages up to 2.5 kg/t on cake thickness and moisture with compliance coal.

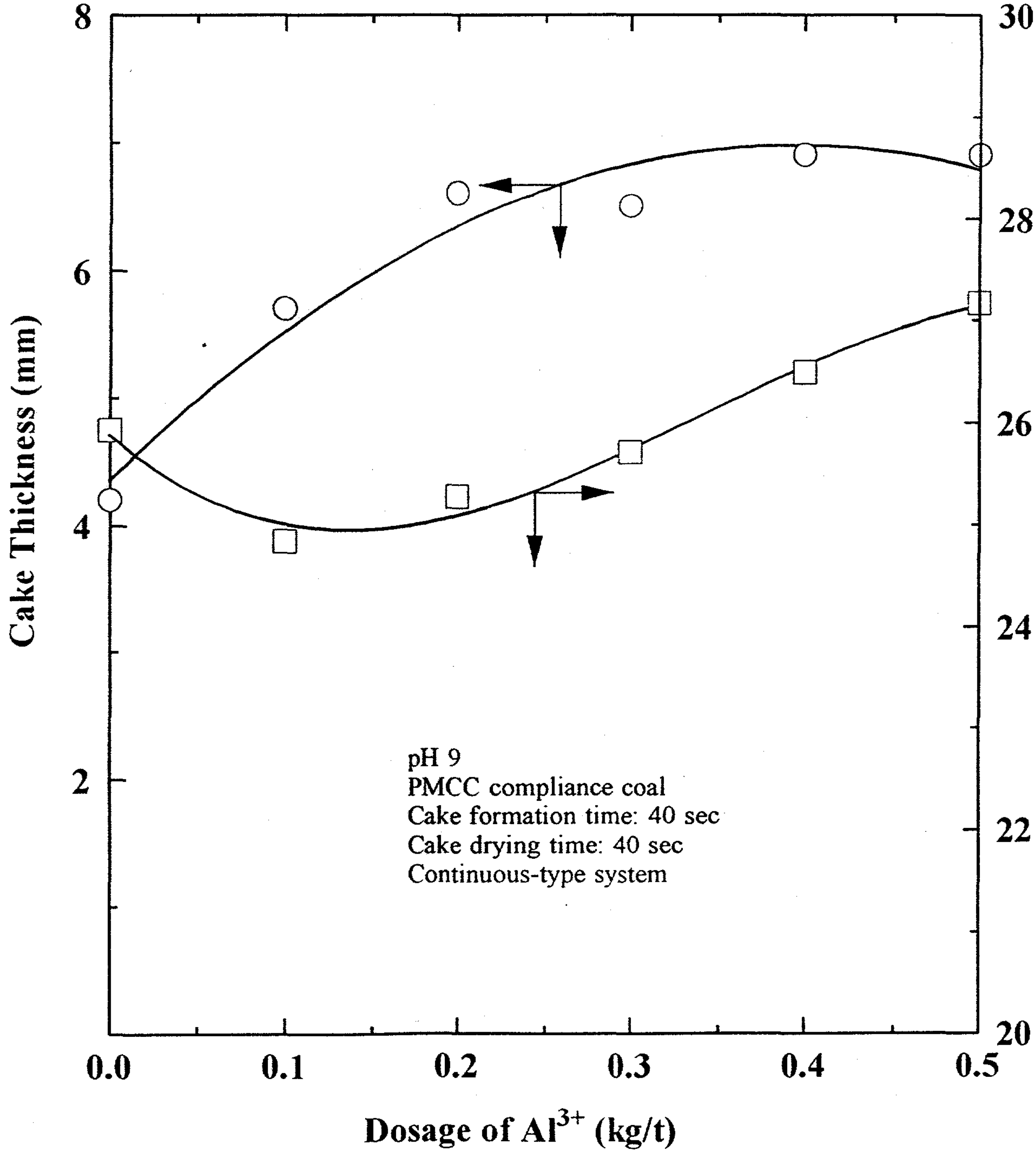

Figure 19. Effect of Al^{3+} at dosages up to 0.5 kg/t on cake thickness and moisture with compliance coal.

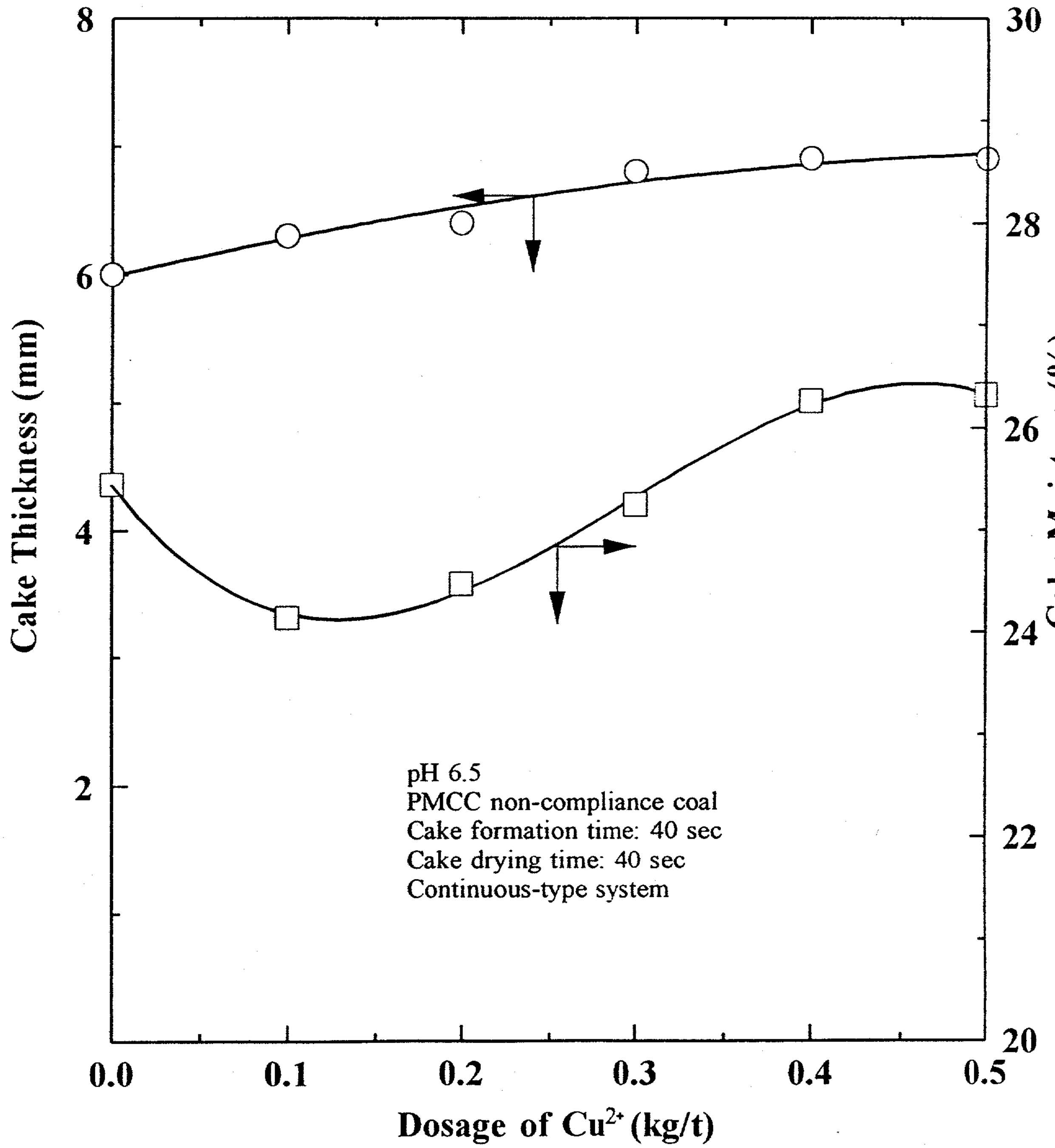

Figure 20. Effect of Cu^{2+} at dosages up to 0.5 kg/t on cake thickness and moisture with non-compliance coal.

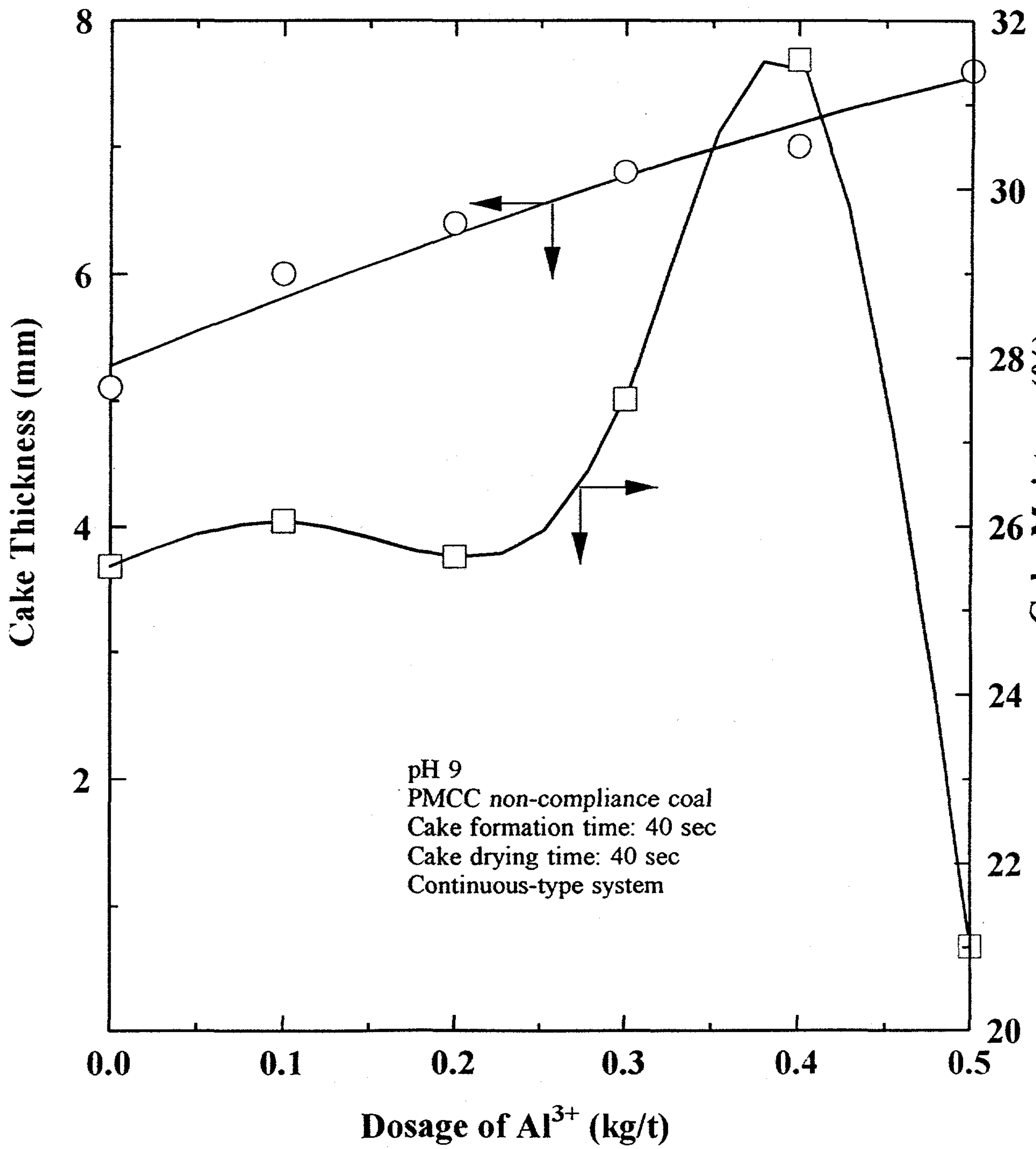

Figure 21. Effect of Al^{3+} at dosages up to 0.5 kg/t on cake thickness and moisture with non-compliance coal.

substantially with further increase in the dosage to 0.4 kg/t. This was followed by a dramatic decrease in cake moisture to 21% at a dosage of 0.5 kg/t.

Cake porosity

To better understand effects of various reagents on coal dewatering behavior, a cake parameter, referred to as cake porosity, was determined for each test described above. The cake porosity, ε, was defined as:

$$\varepsilon = 1 - \frac{4 \times weight\ of\ wet\ cake \times (1 - moisture)}{\pi R_m D^2 \times cake\ thickness}$$

where

R_m: density of coal;

D: diameter of filter leaf, cm;

Weight of wet cake, g;

cake thickness, cm.

Figure 22 shows cake porosity as a function of cake thickness for the compliance coal slurry. It appears that cake porosity was independent of cake thickness and more importantly, addition of various reagents did not affect the cake porosity. Although cake porosity was relatively constant in all these tests, cake moisture differed considerably, as shown in Figure 23. This suggests that cake porosity is not important in determining cake moisture for this specific coal. Relatively low cake moisture, e.g., less than 23%, can be achieved by use of flocculant or surfactant. However, use of surfactant did not increase cake thickness, as shown in Figure 24. Flocculant appears to the most effective

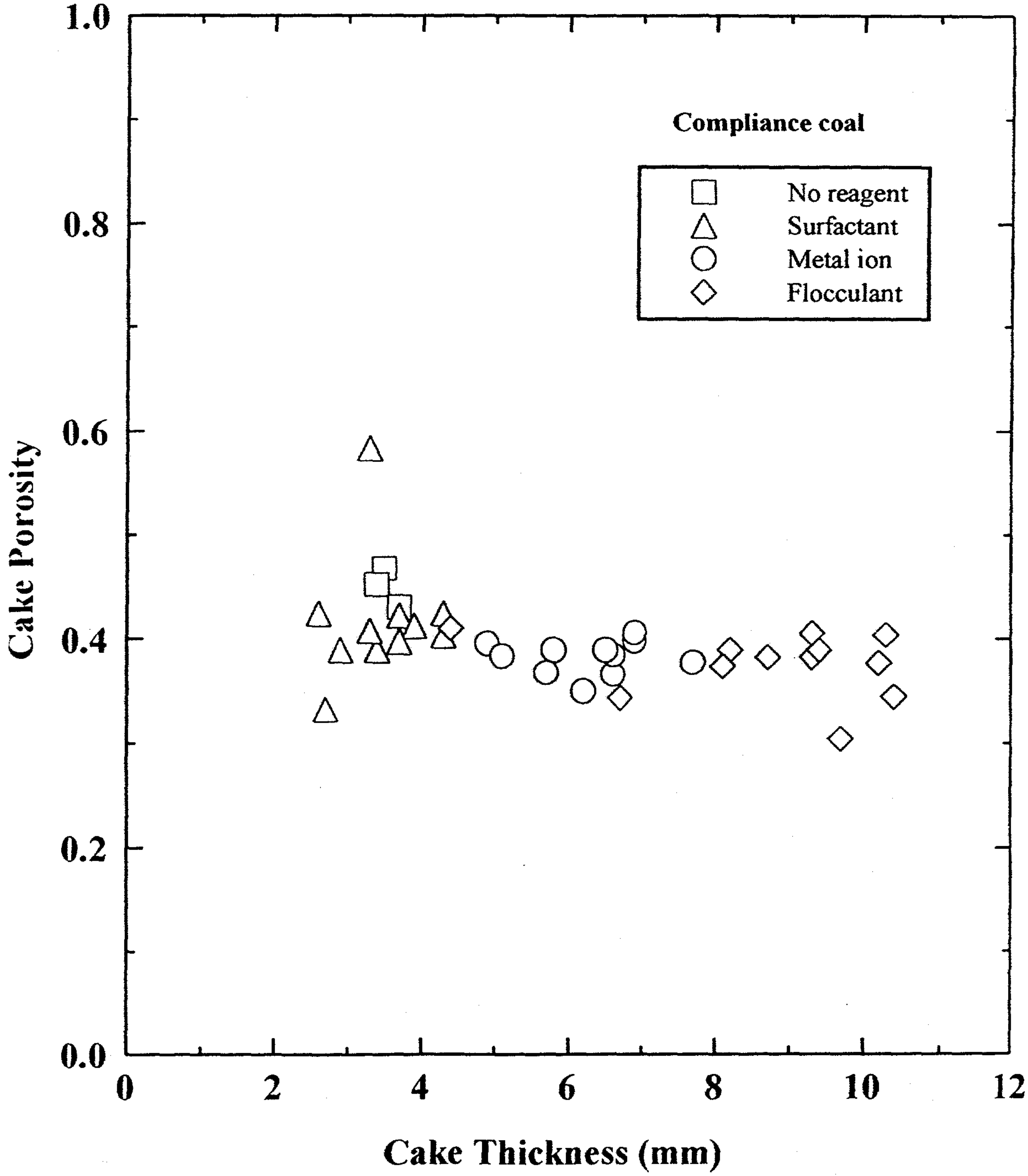

Figure 22. Cake porosity as a function of cake thickness with compliance coal.

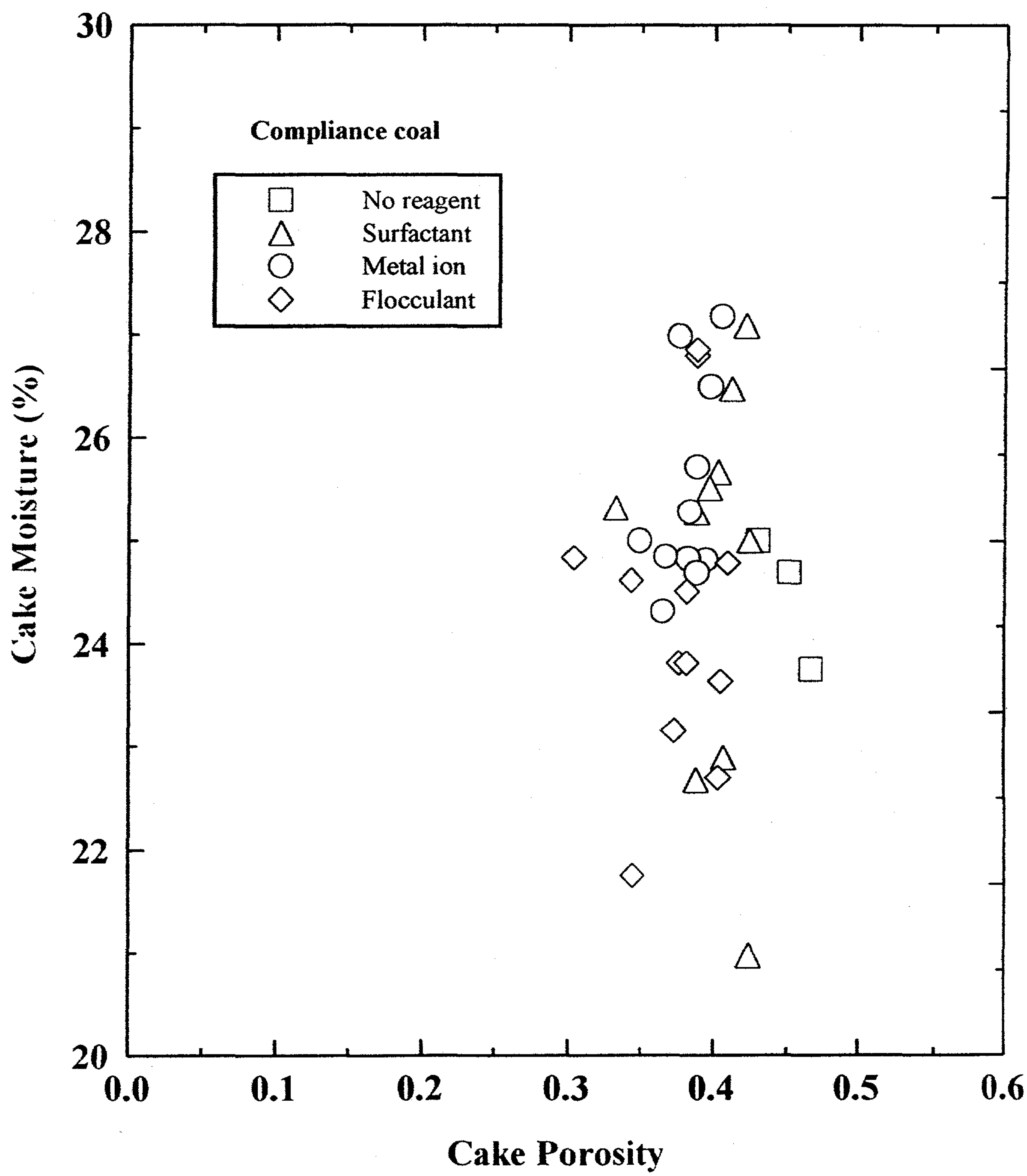

Figure 23. Cake moisture as a function of cake porosity with compliance coal.

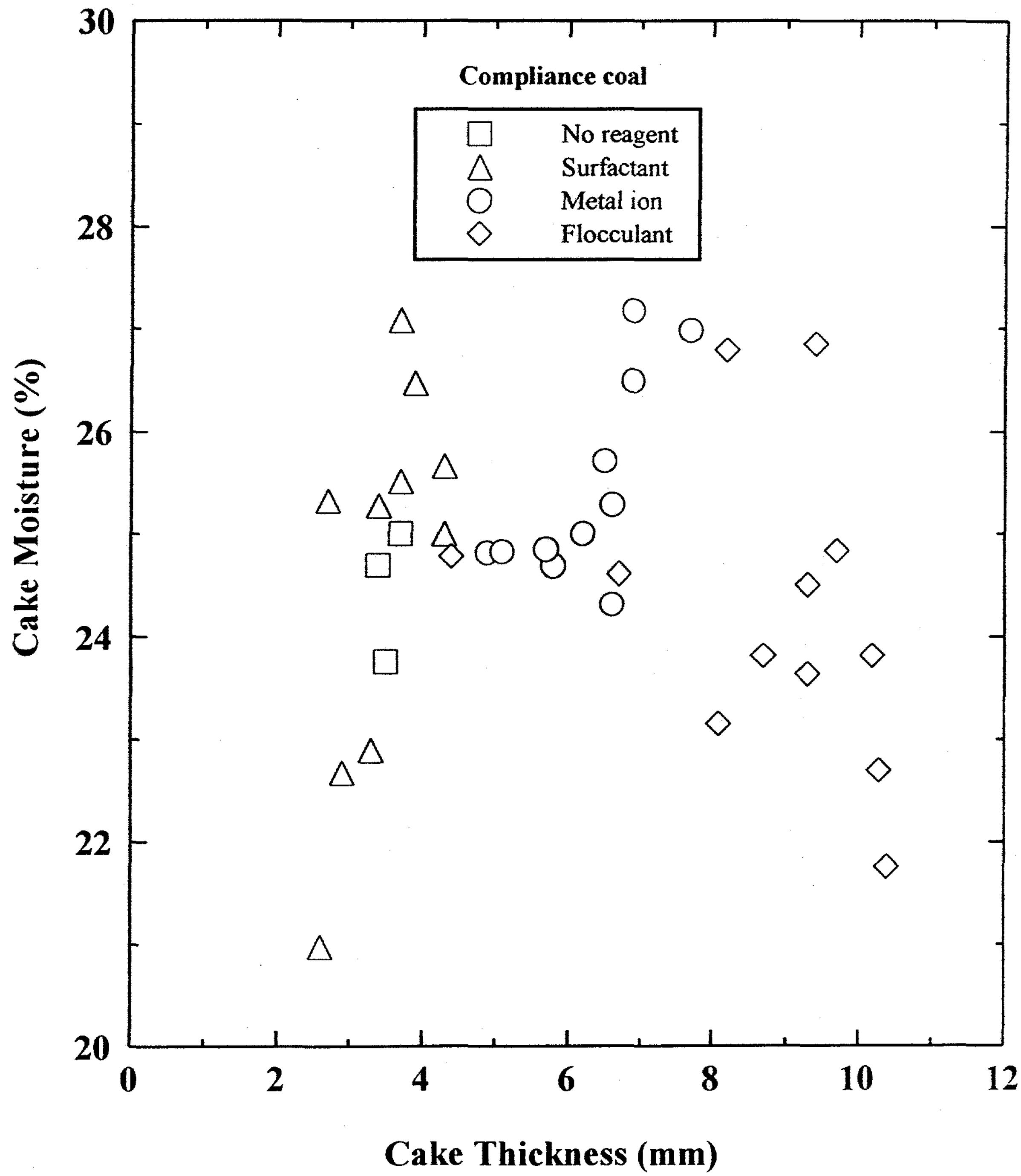

Figure 24. Cake moisture as a function of cake thickness with compliance coal.

reagent to enhance coal dewatering. It generated thicker and drier cake. Figure 24 also indicates that use of surfactant or metal ion alone likely have adverse effects on cake moisture when thicker cake was produced.

Figure 25 shows the dependence of cake porosity on cake thickness with the non-compliance coal. Addition of surfactant and metal ion had marginal effects on cake porosity. Use of flocculant significantly increased cake thickness but reduced cake porosity.

Figure 26 shows cake moisture as a function of cake porosity for the non-compliance coal slurry. Data in this figure scatter over a wide range, indicating that there is no significant correlation between cake moisture and cake porosity. It is noticed that all six data points close to the lower left corner were obtained in the presence of cationic flocculant.

Figure 27 shows the dependence of cake moisture on cake thickness with the non-compliance coal. Use of surfactant or metal ion increased cake thickness by approximately 1 mm but remarkably increased cake moisture. However, use of flocculant was able to substantially increase cake thickness. The cake moisture in the presence of flocculant depends on the dosage and type of flocculant.

Task 6. System Operation

Pilot-scale vacuum filtration testing was conducted to determine the effect of flocculant type and dosage on cake moisture and throughput. The surfactants utilized in this phase of the investigation were Percol 157, an anionic flocculant

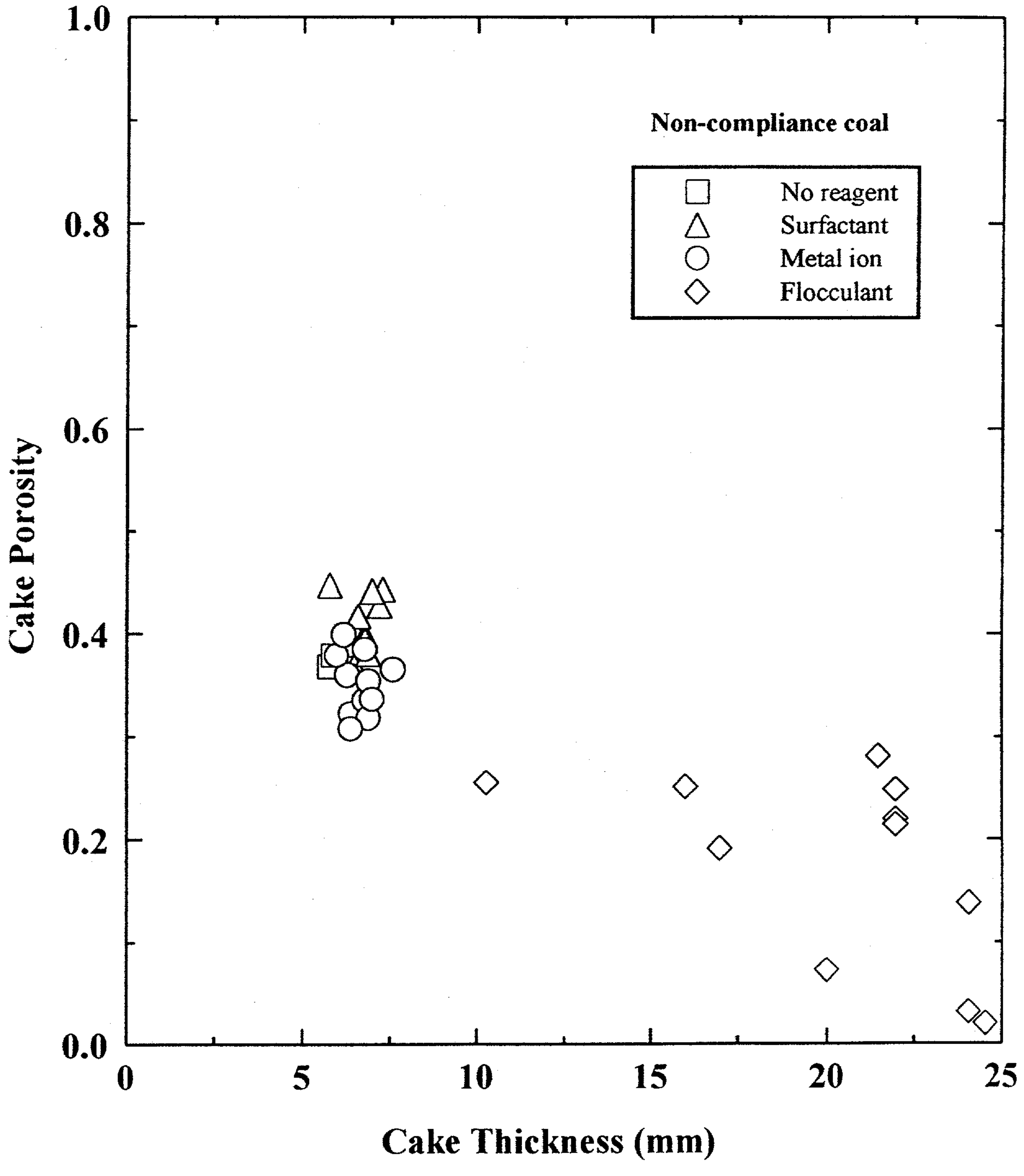

Figure 25. Cake porosity as a function of cake thickness with compliance coal.

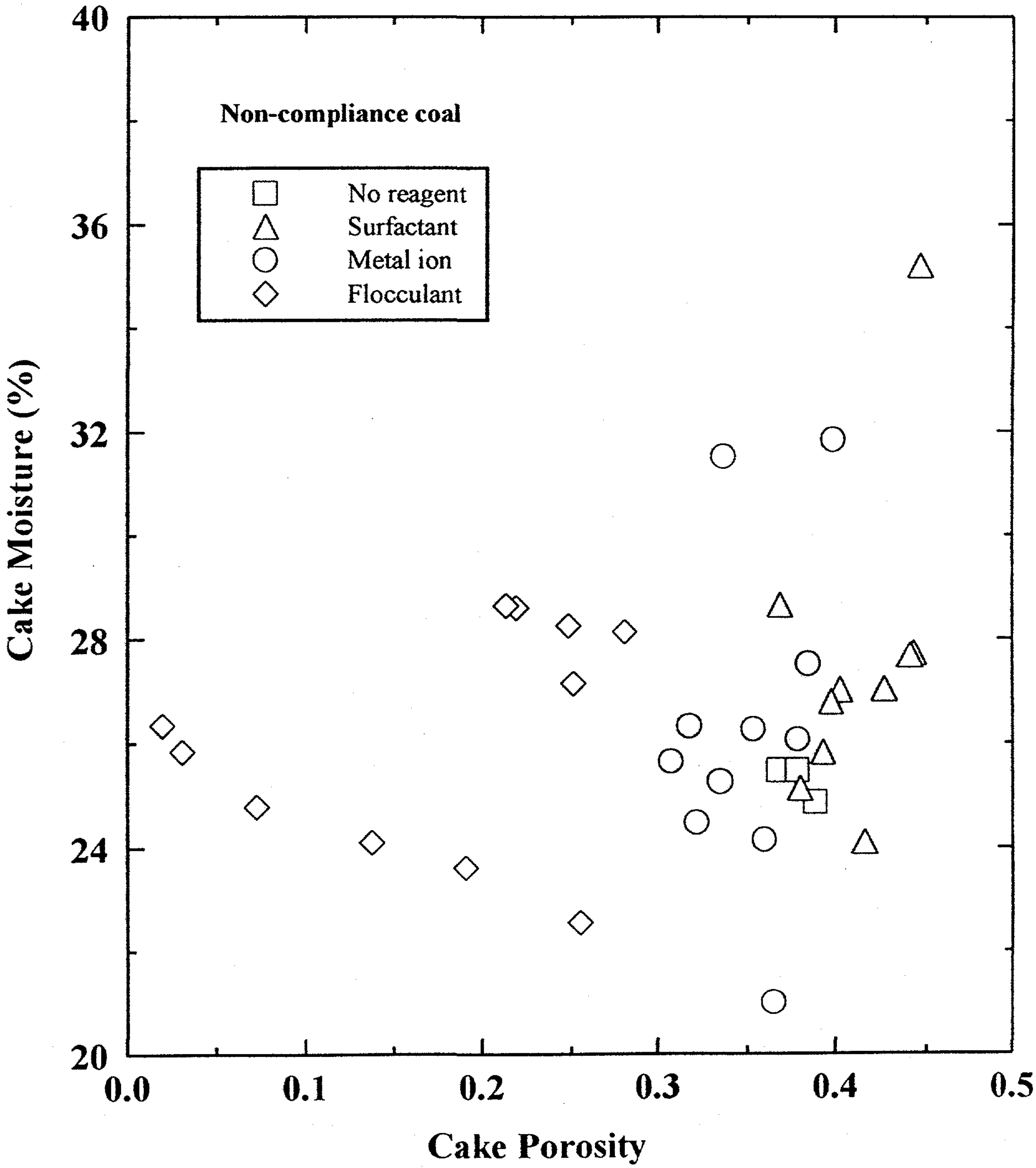

Figure 26. Cake moisture as a function of cake porosity with compliance coal.

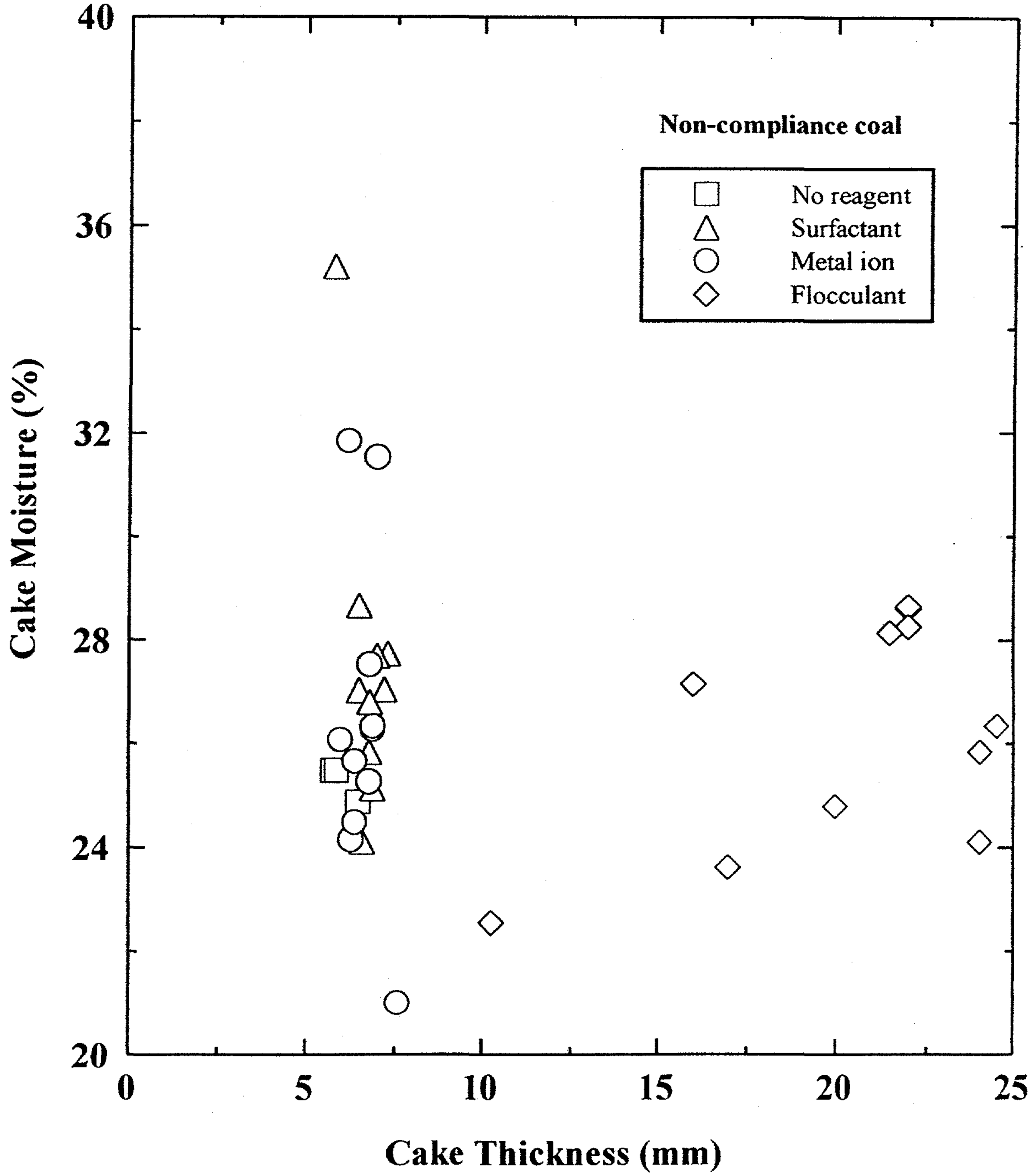

Figure 27. Cake moisture as a function of cake thickness with compliance coal.

with a molecular weight of approximately 12M and Percol 371, a cationic flocculant with a molecular weight of approximately 4 M. In each test, the drum speed was held constant at 1 rpm and the slurry feed rate was controlled to maintain the filter tub level to allow for maximum drum submergence. Baseline testing was conducted before and after each series of tests utilizing surfactant to ensure that all residual surfactant was removed from the system.

The effect of anionic flocculant dosage on cake moisture for the non-compliance high sulfur coal slurry is shown in Figure 28. Baseline tests produced a filter cake containing 27.9% moisture. Increasing anionic flocculant dosage decreased cake moisture. At the lowest dosage of flocculant tested (5 gpt), the canionic flocculant reduced the cake moisture to 27.2% while further increasing the dosage to 20 gpt reduced the cake moisture to 25.0%. The cationic flocculant actually increased cake moisture for the entire dosage range tested. From a baseline of 25.0% moisture, the addition of 5 to 20 gpt of cationic flocculant increased cake moisture from 26.2 to 28.2%.

The effect of flocculant dosage on throughput for the high sulfur coal is summarized in Figure 29. In general, both flocculants increased throughput as the flocculant dosage was increased, particularly the anionic flocculant. Cationic flocculant increased throughput from 20 to 30 $lb/ft^2/hr$ as the dosage was increased from 0 to 15 gpt. At the highest dosage of 20 gpt, no additional throughput occurred. Similar results were achieved with anionic flocculant, however the overall throughput was higher (25 to 47 $lb/ft^2/hr$). The higher

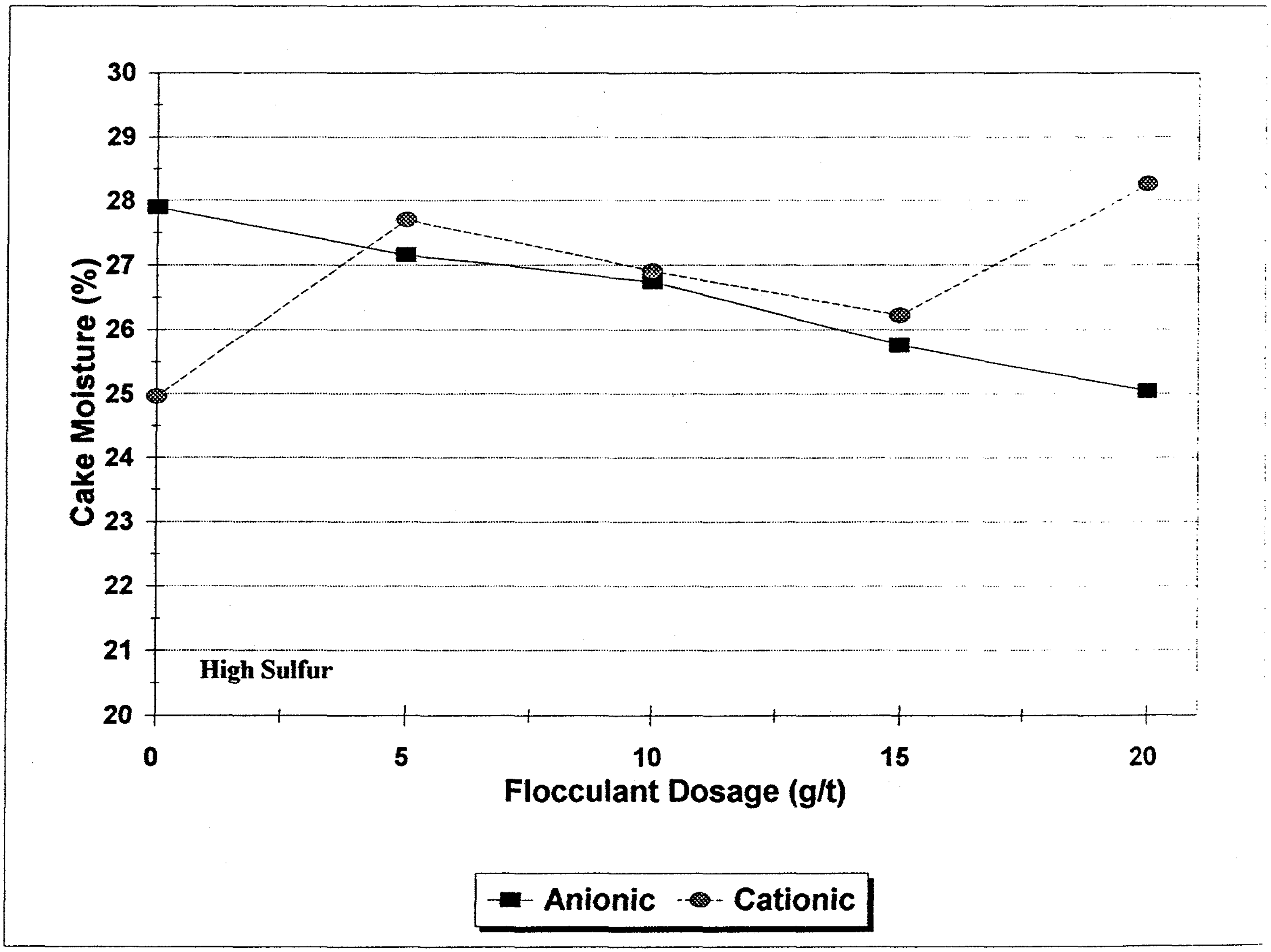

Figure 28. Effect of Anionic and Cationic Flocculant Dosage on Cake Moisture for POC Testing with High Sulfur Coal.

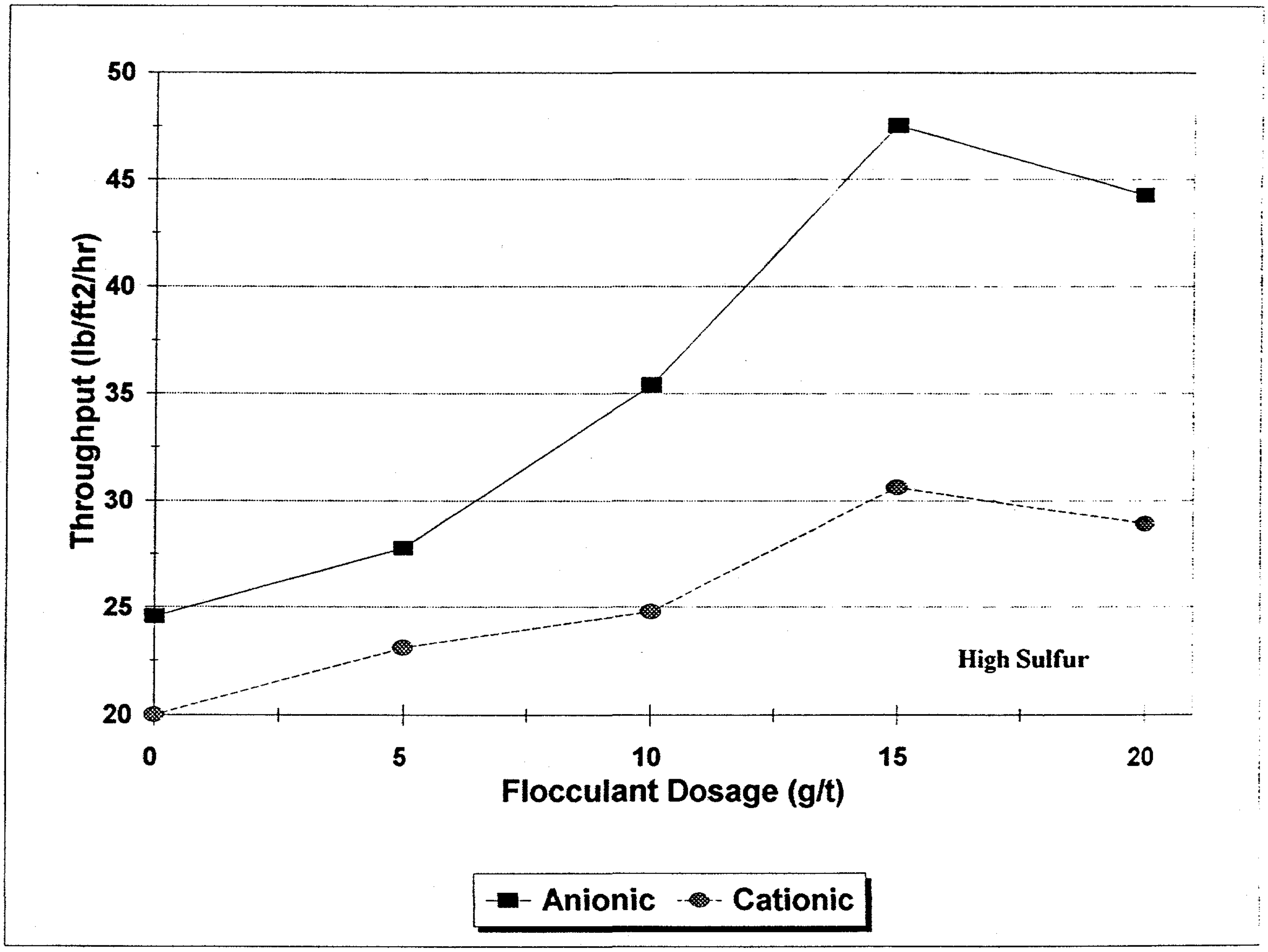

Figure 29. Effect of Anionic and Cationic Flocculant Dosage on Throughput for POC Testing with High Sulfur Coal.

throughput obtained with anionic flocculant on the high sulfur coal was achieved while reducing cake moisture while the slightly higher throughput achiceved with the cationic flocculant resulted in higher cake moisture .

For flocculant dosage tests using compliance low sulfur coal slurry, different cake moisture results were obtained in comparison with the high sulfue coal (Figure 30). Increasing cationic flocculant dosage to 15 gpt reduced moisture from a baseline of 24% moisture to as low as 21.2% moisture. Higher dosages of cationic flocculant provided no further moisture reduction. The addition of 5 gpt anionic flocculant reduced the cake moisture from a baseline of 26.9% moisture to 24.2% moisture. However, at higher dosages of anionic flocculant (10 to 20 gpt) cake moisture was essentially the same as the baseline.

As observed with the high sulfur coal, the addition of flocculant increased throughput with the compliance coal as shown in Figure 31. When the cationic flocculant was used, there was no change in throughput when a low dosage of <10 gpt was used. At higher dosages of cationic flocculant, a marginal increase in throughput occurred from 18 to 21 $lb/ft^2/hr$. However, when anionic flocculant was used, the throughput increased from 14.8 $lb/ft^2/hr$ to 24 $lb/ft^2/hr$ as the dosage was increased from 0 to 15 gpt. Further increasing the dosage of anionic flocculant to 20 gpt did not provide any further increase in throughput. For the compliance coal, anionic flocculant increased throughput with no change in cake moisture while cationic flocculant slightly increased throughput while decreasing cake moisture.

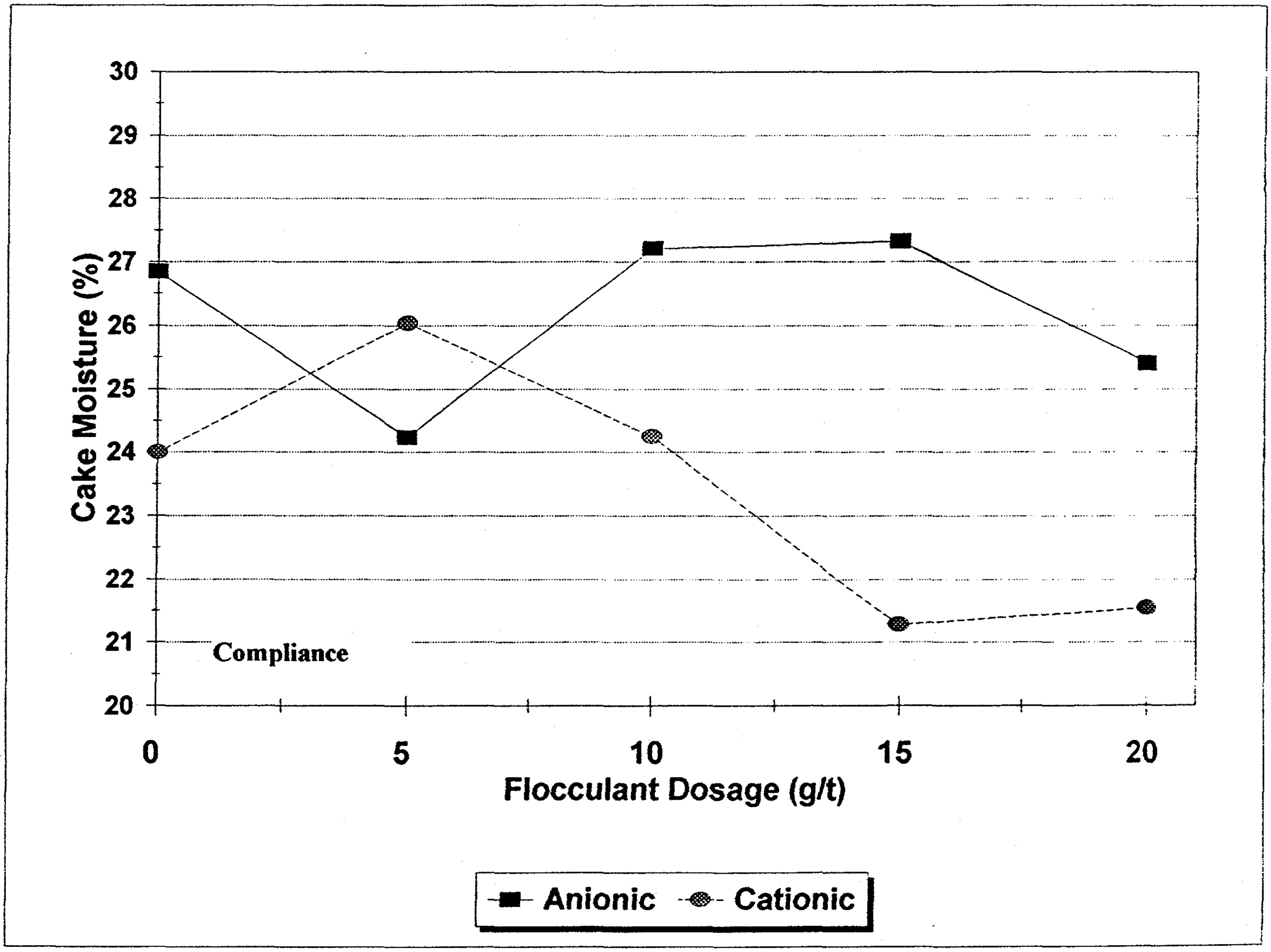

Figure 30. Effect of Anionic and Cationic Flocculant Dosage on Cake Moisture for POC Testing with Compliance Coal.

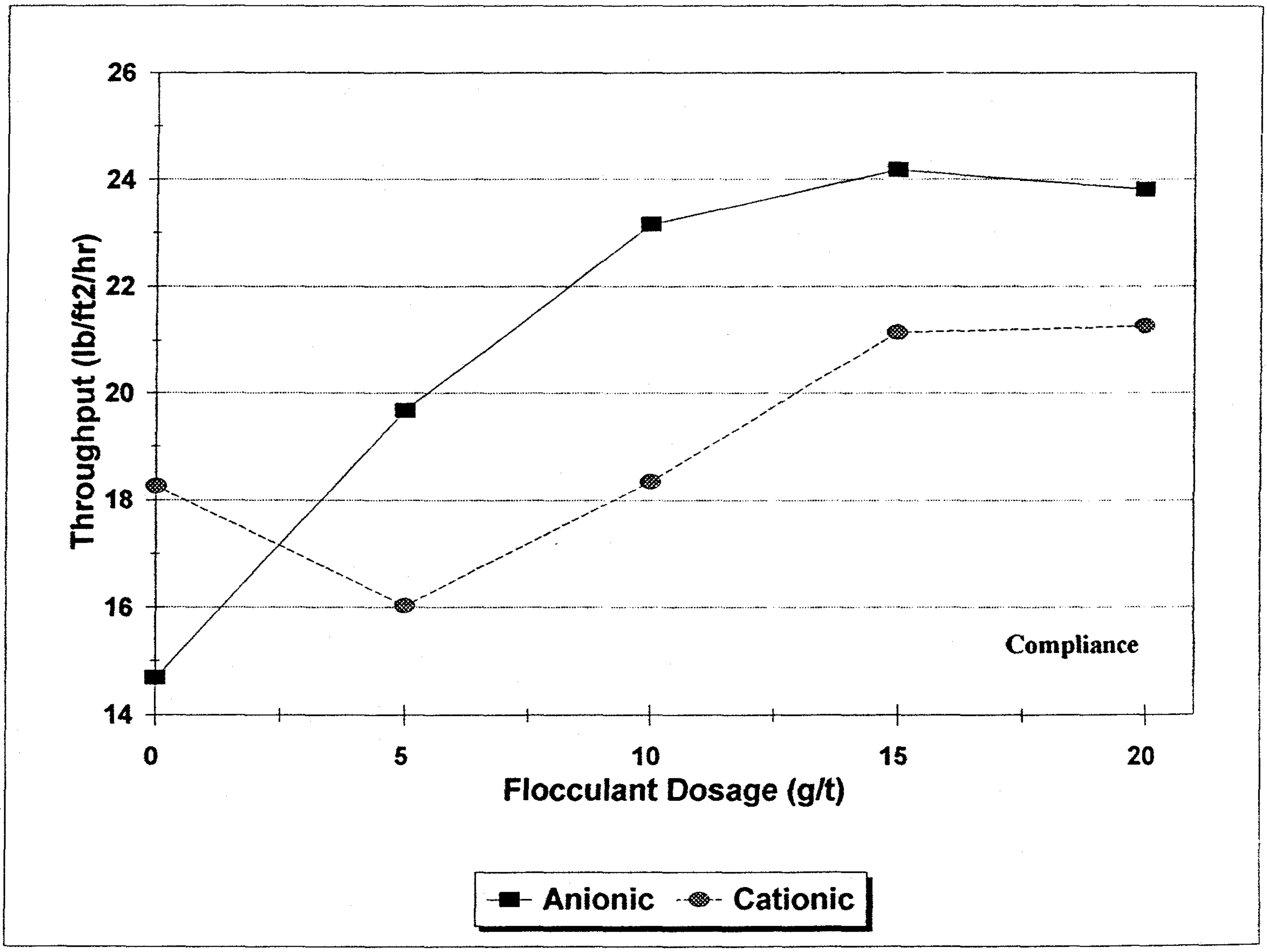

Figure 31. Effect of Anionic and Cationic Flocculant Dosage on Throughput for POC Testing with Compliance Coal.

A comparison of the results obtained with anionic flocculant with both coals is shown in Figure 32. Increasing anionic flocculant dosage from 0 to 20 gpt resulted in lowering cake moisture for the high sulfur coal from 28 to 25% moisture. For the compliance coal, a dosage of only 5 gpt anionic flocculant was sufficient to reduce cake moisture from 26.9 to 24.2% moisture, but higher doasges produced results that were similar to the baseline. The resulting throughputs from these tests are summarized in Figure 33. When the anionic flocculant was used on the high sulfur coal, throughput increased with increasing flocculant dosage and nearly doubled from 25 to 47 $lb/ft^2/hr$ by increasing the anionic flocculant dosage from 0 to 15 gpt. For the compliance coal, the throughput was again nearly doubled by the addition of 15 gpt anionic flocculant, increased from 15 to 24.8 $lb/ft^2/hr$. The higher throughputs obtained with the high sulfur coal is attributed to higher feed solids.

For the cationic flocculant, cake moisture with the compliance coal was reduced from 24 to 21.5% moisture at a dosage of 15 gpt as shown in Figure 34. Increasing the dosage to 20 gpt did not reduced cake moisture any further. For the high sulfur coal, cake moisture increased as cationic flocculant dosage was increased. Increasing the dosage from 0 to 20 gpt increased moisture from 25 to 28.2%. These results show that the cationic flocculant was more effective for reducing moisture with the compliance coal.

The throughput obtained with the complaine coal was essentially unchanged by increasing cationic flocculant dosage as shown in Figure 35. The

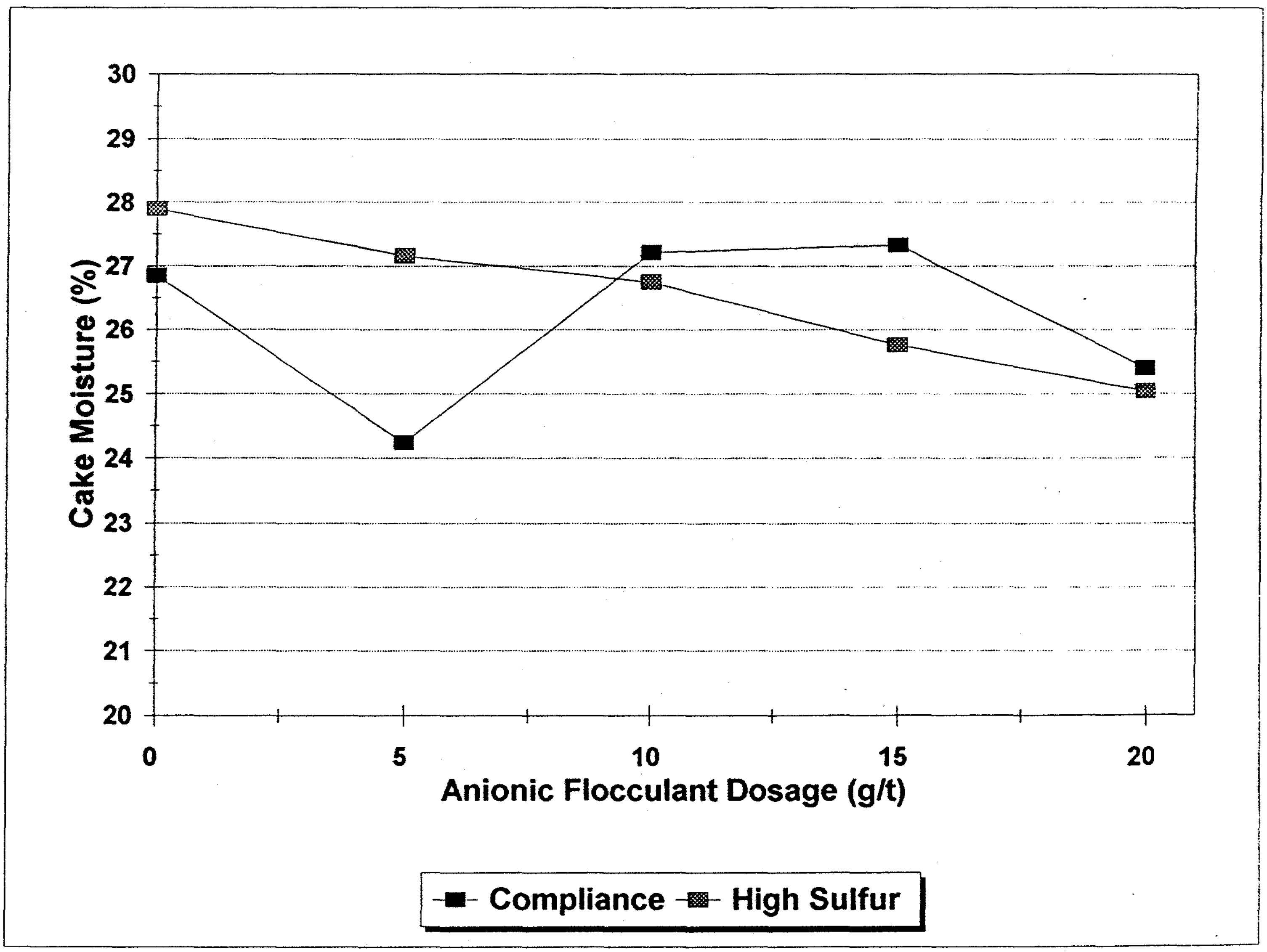

Figure 32. Effect of Anionic Flocculant Dosage on Cake Moisture for POC Testing with High Sulfur and Compliance Coal.

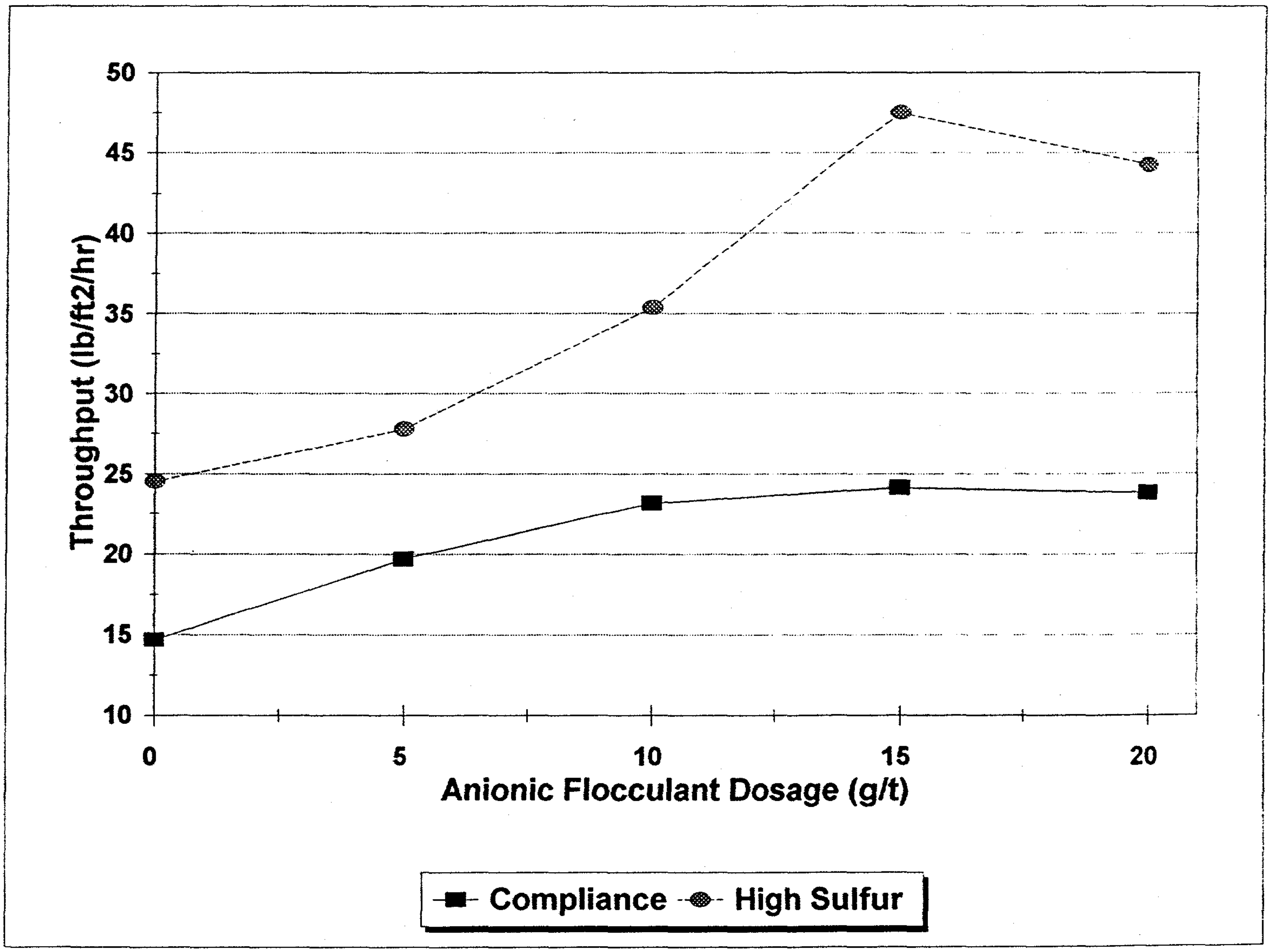

Figure 33. Effect of Anionic Flocculant Dosage on Throughput for POC Testing with High Sulfur and Compliance Coal.

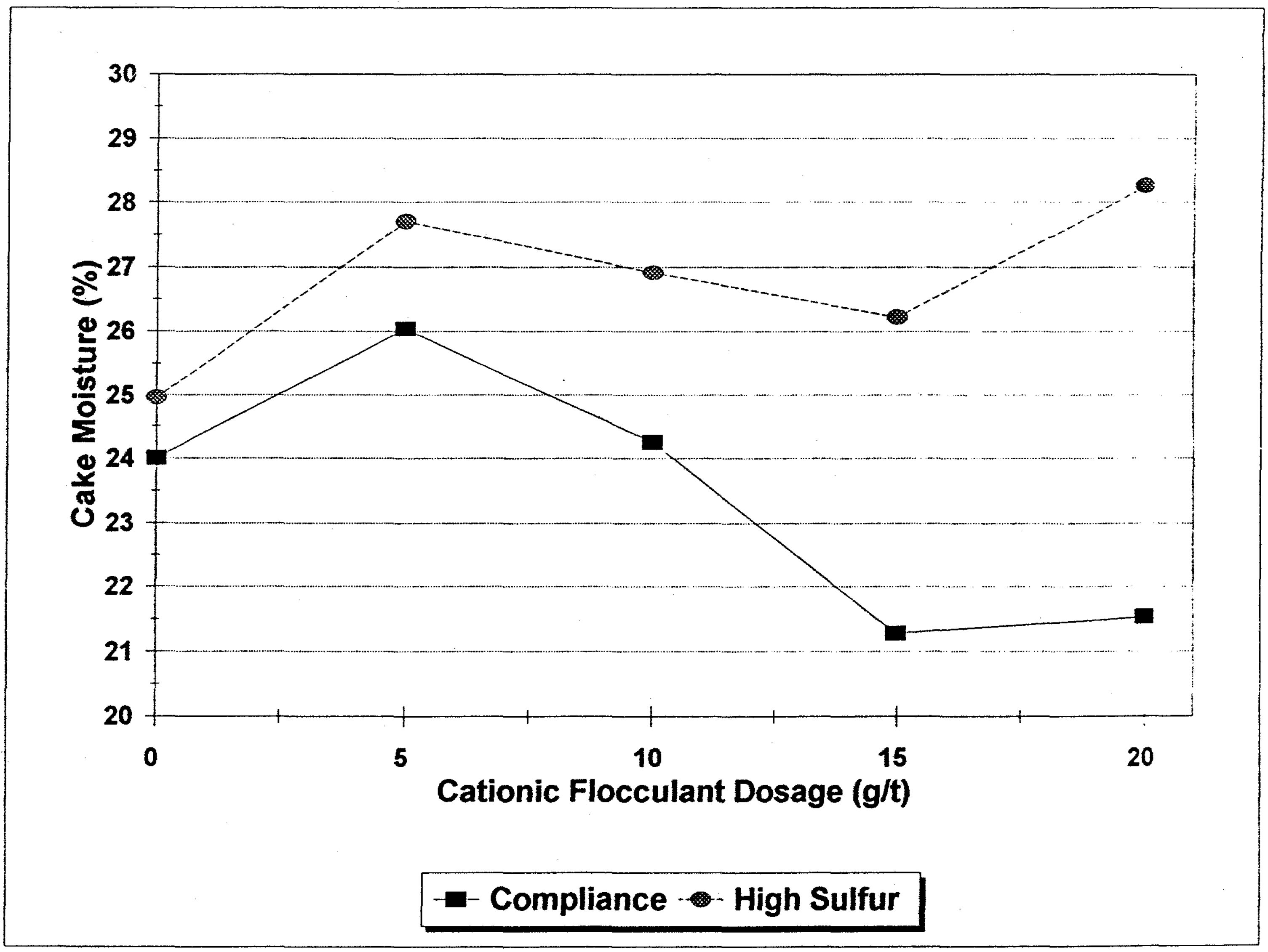

Figure 34. Effect of Cationic Flocculant Dosage on Cake Moisture for POC Testing with High Sulfur and Compliance Coal.

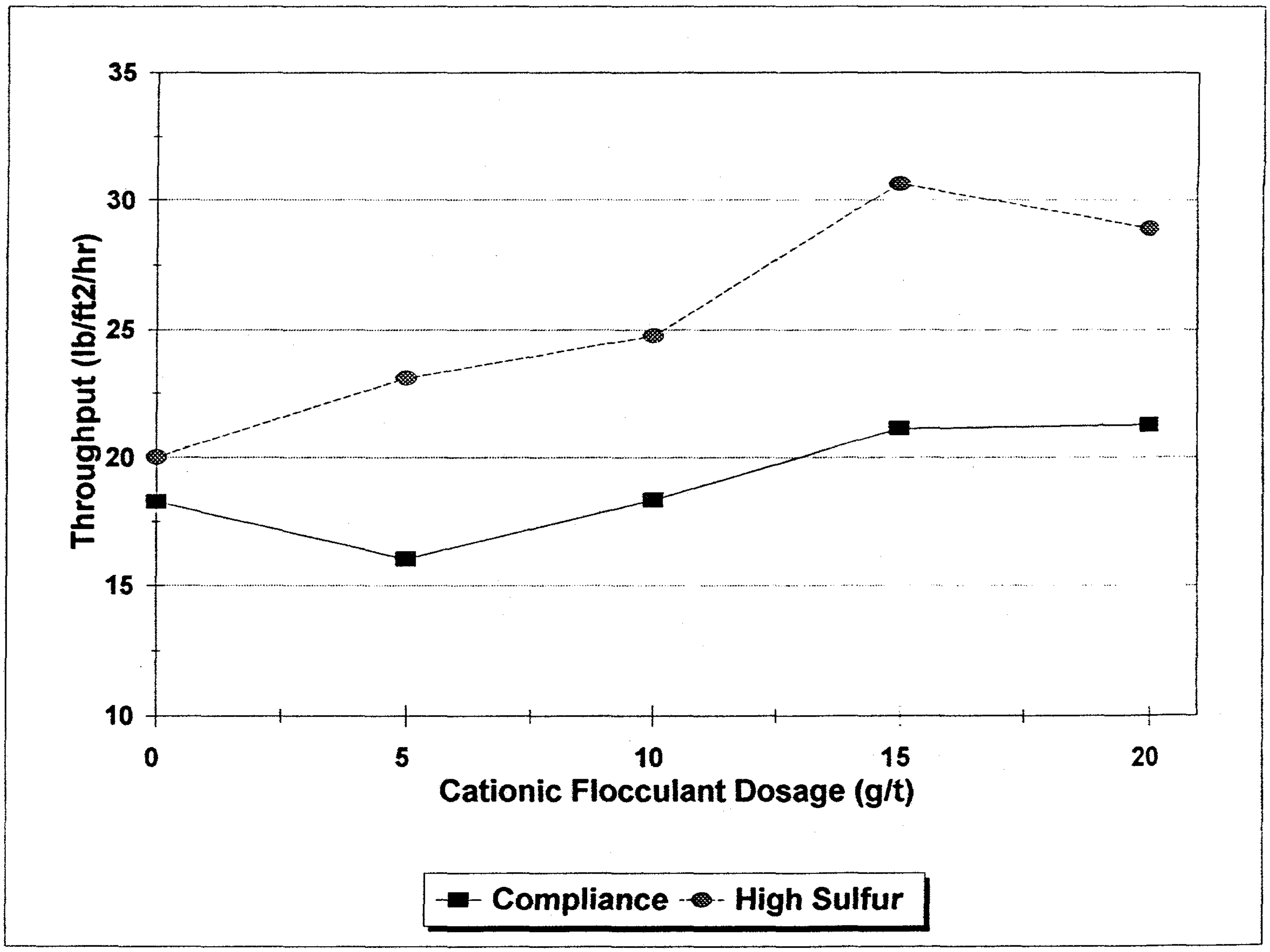

Figure 35. Effect of Cationic Flocculant Dosage on Throughput for POC Testing with High Sulfur and Compliance Coal.

throughput was 15.5 to 21 $lb/ft^2/hr$ throughout the dosage range tested. For the high sulfur coal, the throughput increased with increasing dosage from a baseline throughput of 20 $lb/ft^2/hr$ to 31 $lb/ft^2/hr$ at a dosage of 15 gpt.

The effect of $CuCl_2$ dosage on cake moisture is shown in Figure 36. For the high sulfur coal, no change in moisture was observed until the dosage was increased to 500 mg/kg which reduced moisture from 27 to 24.8%. Increasing the dosage to as high as 1000 mg/kg resulted in a slightly increased cake moisture of 25.6%. For the compliance coal, cake misture was reduced from 27.9% to 26.2% by the addition of 500 mg/kg $CuCl_2$. Increasing the dosage to 1000 mg/kg produced no change in cake moisture.

The effect of $CuCl_2$ on throughput is summarized in Figure 37. For both substrates, no change in throughput was observed until the $CuCl_2$ dosage was 500 mg/kg. For the compliance coal, the throughput increased from 25 to 31 $lb/ft^2/hr$ at this dosage and further increased to 36.5 $lb/ft^2/hr$ at a dosage of 1000 mg/kg. For the high sulfur coal, at a $CuCl_3$ dosage of 500 mg/kg, the throughput doubled from 18 to 36 $lb/ft^2/hr$. These results show that the effect of $CuCl_3$ is similar to that of flocculant. Throughput was significantly increased for both substrates while cake moisture was reduced.

The addition of $AlCl_3$ also provided cake moisture reduction as shown in Figure 38. For the compliance coal, the addition of 100 mg/kg $AlCl_3$ reduced cake moisture from a baseline of 27.9 % to 26.6% moisture. Increasing the dosage to as high as 1000 mg/kg did not provide any additional moisture

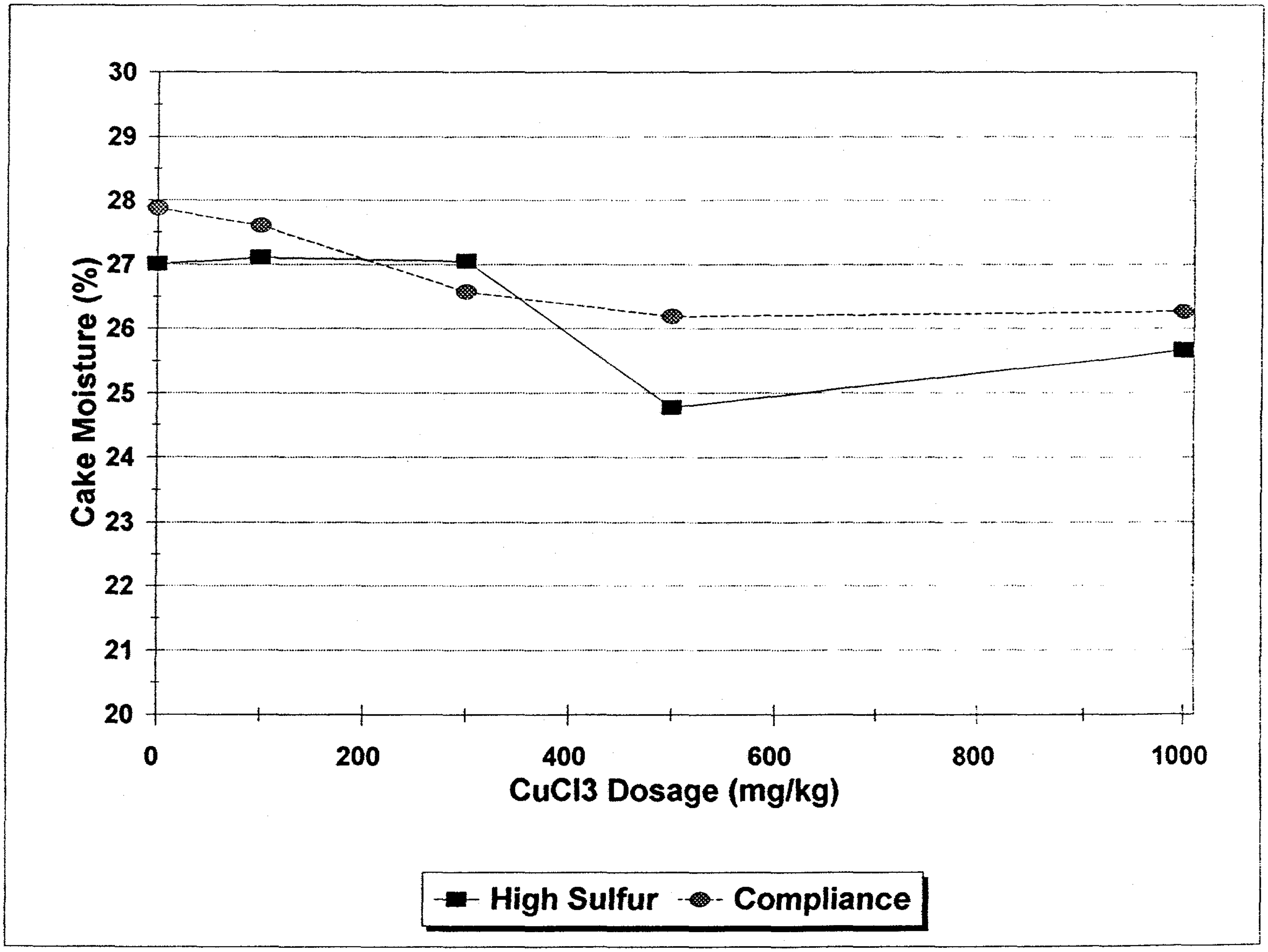

Figure 36. Effect of $CuCl_2$ Dosage on Cake Moisture for POC Testing with High Sulfur and Compliance Coal.

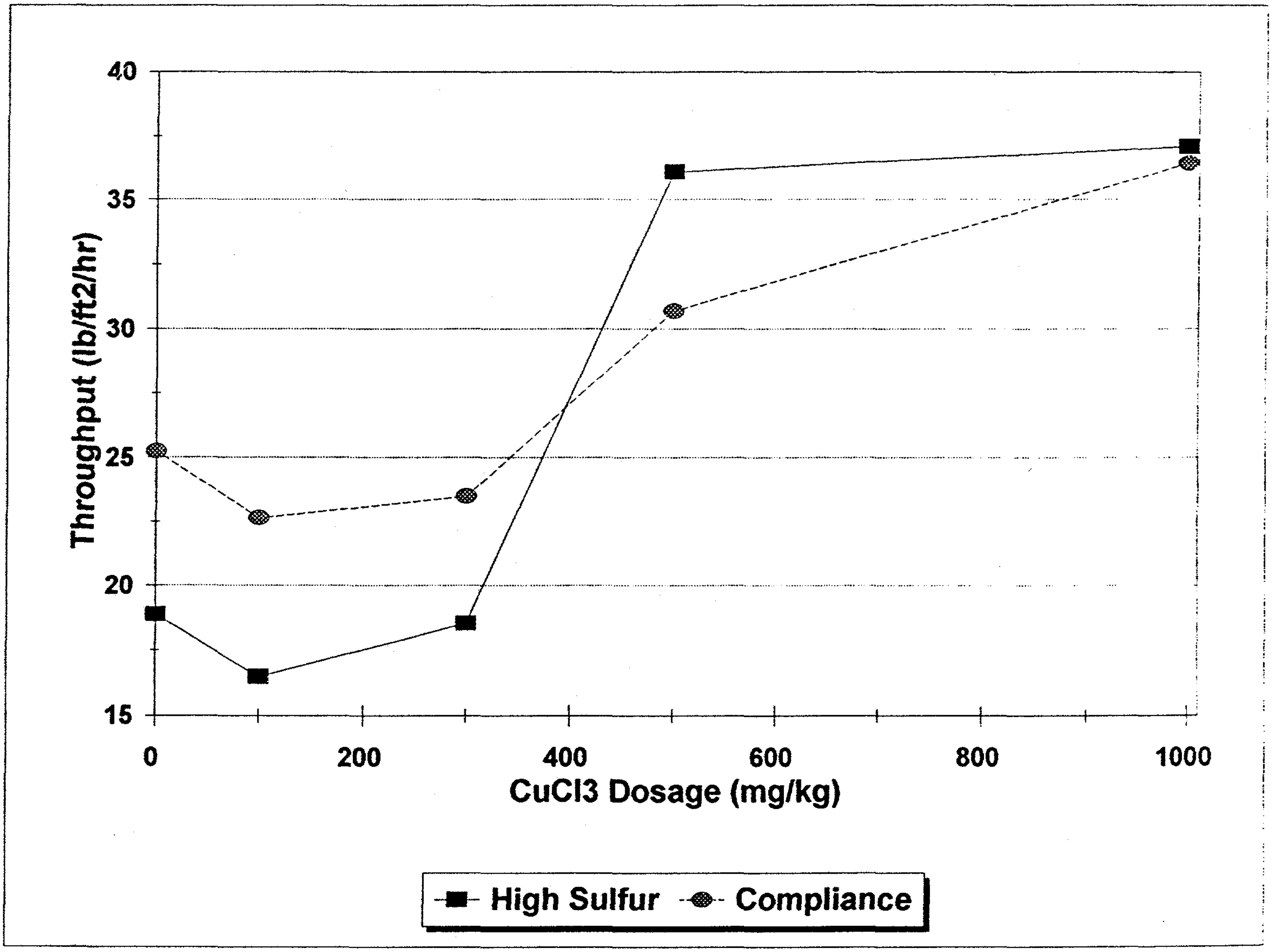

Figure 37. Effect of $CuCl_2$ Dosage on Throughput for POC Testing with High Sulfur and Compliance Coal.

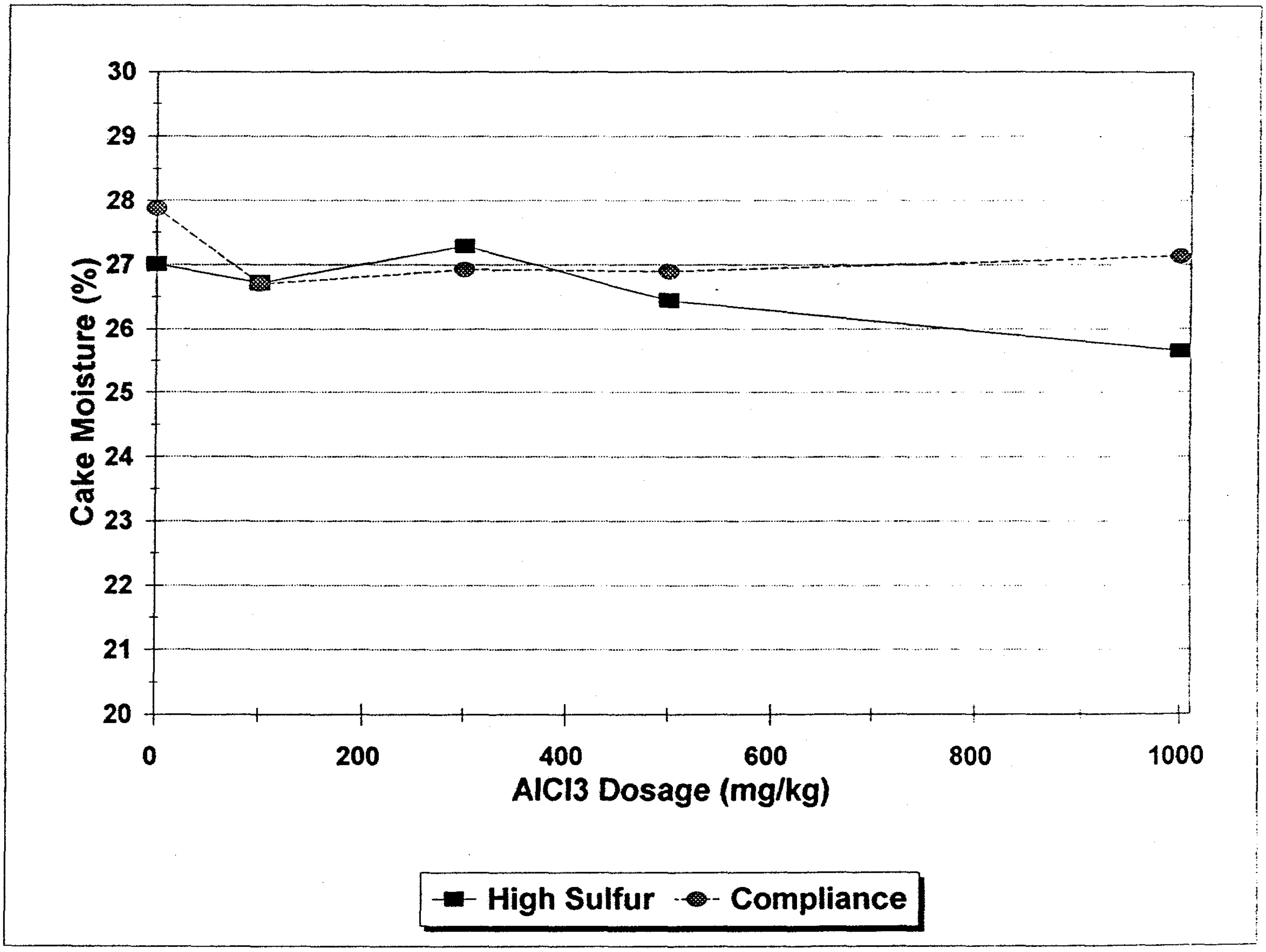

Figure 38. Effect of $AlCl_3$ Dosage on Cake Moisture for POC Testing with High Sulfur and Compliance Coal.

removal. For the high sulfur coal, cake moisture remained essentially unchanged with increasing $AlCl_3$ dosage to as high as 500 mg/kg, which produced cake mositures of 27 to 26.5% moisture. A slight reduction in cake moisture to 25.7% was obtained at a dosage of 1000 mg/kg. Throughput achieved with the compliance coal remained unchanged at 25 $lb/ft^2/hr$ at $AlCl_3$ dosages as high as 500 mg/kg as shown in Figure 39. Further increasing the dosage to 1000 mg/kg increased throughput to 34 $lb/ft^2/hr$. For the high sulfur coal, throughput actually decreased at low $AlCl_3$ dosages and ultimately achieved the same throughput achieved with the compliance coal at a dosage of 1000 mg/kg.

The results of cake moistures obtained with $FeCl_3$ are summarized in Figure 40. For the compliance coal, increasing the $FeCl_3$ dosage from 0 to 300 mg/kg reduced cake moisture from a baseline of 28.1% to 27.1%. Further increasing the $FeCl_3$ dosage did not provide any further moisture reduction. For the high sulfur coal, a decrease from a baseline of 26.5% to 25.5% occurred with the addition of 100 mg/kg $FeCl_3$. At the highest dosage tested (1000 mg/kg) cake moisture was reduced to as low as 23.8%. As with the other metal salts tested, increasing $FeCl_3$ dosage resulted in increased throughput as shown in Figure 41. For the high sulfur coal, a modest increase in throughput occurred with a dosage of 100 mg/kg $FeCl_3$, increasing from 17.5 to 22 $lb/ft^2/hr$. At a dosage of 1000 mg/kg, throughput further increased to 27 $lb/ft^2/hr$. For the

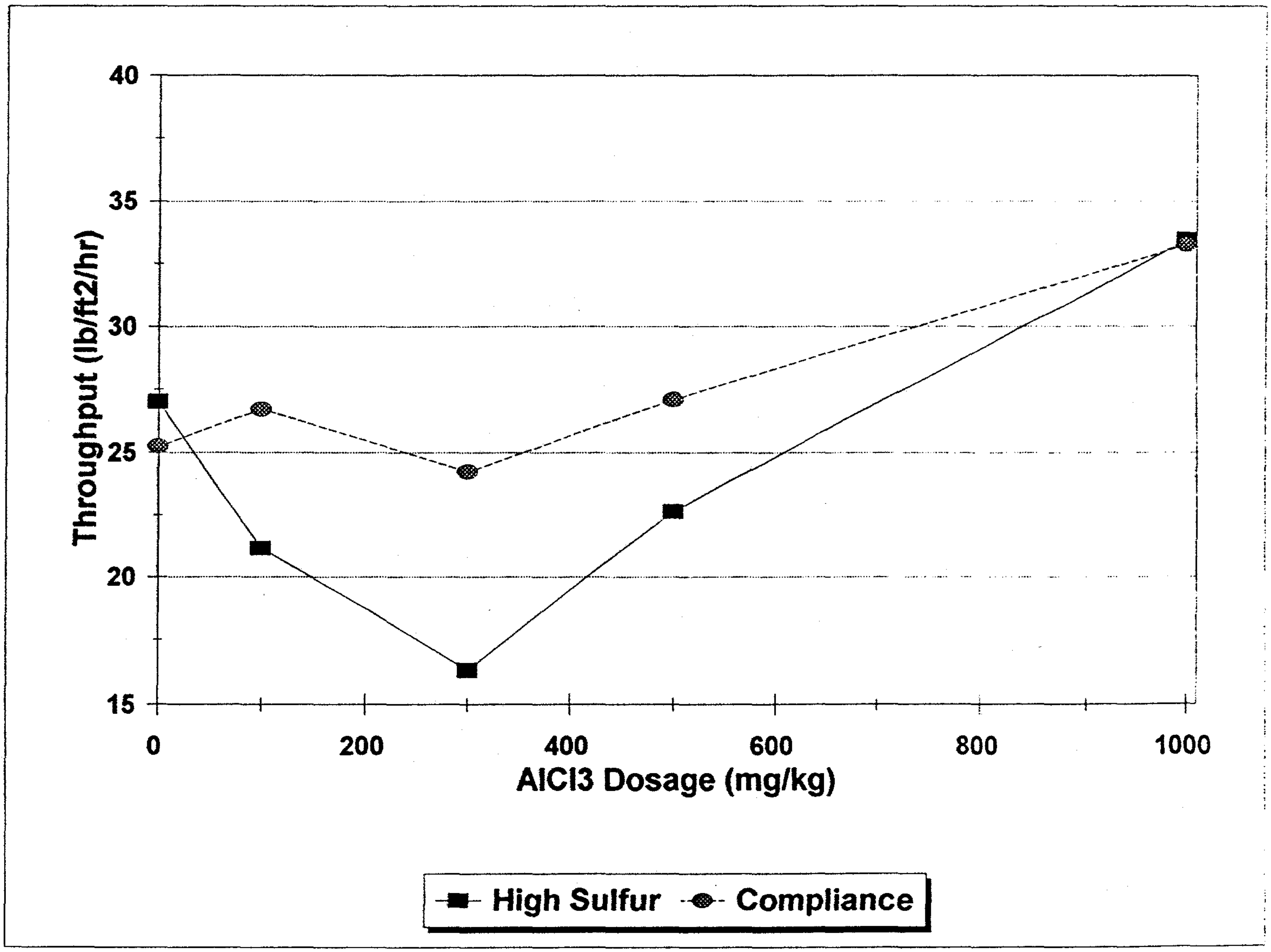

Figure 39. Effect of $AlCl_3$ Dosage on Throughput for POC Testing with High Sulfur and Compliance Coal.

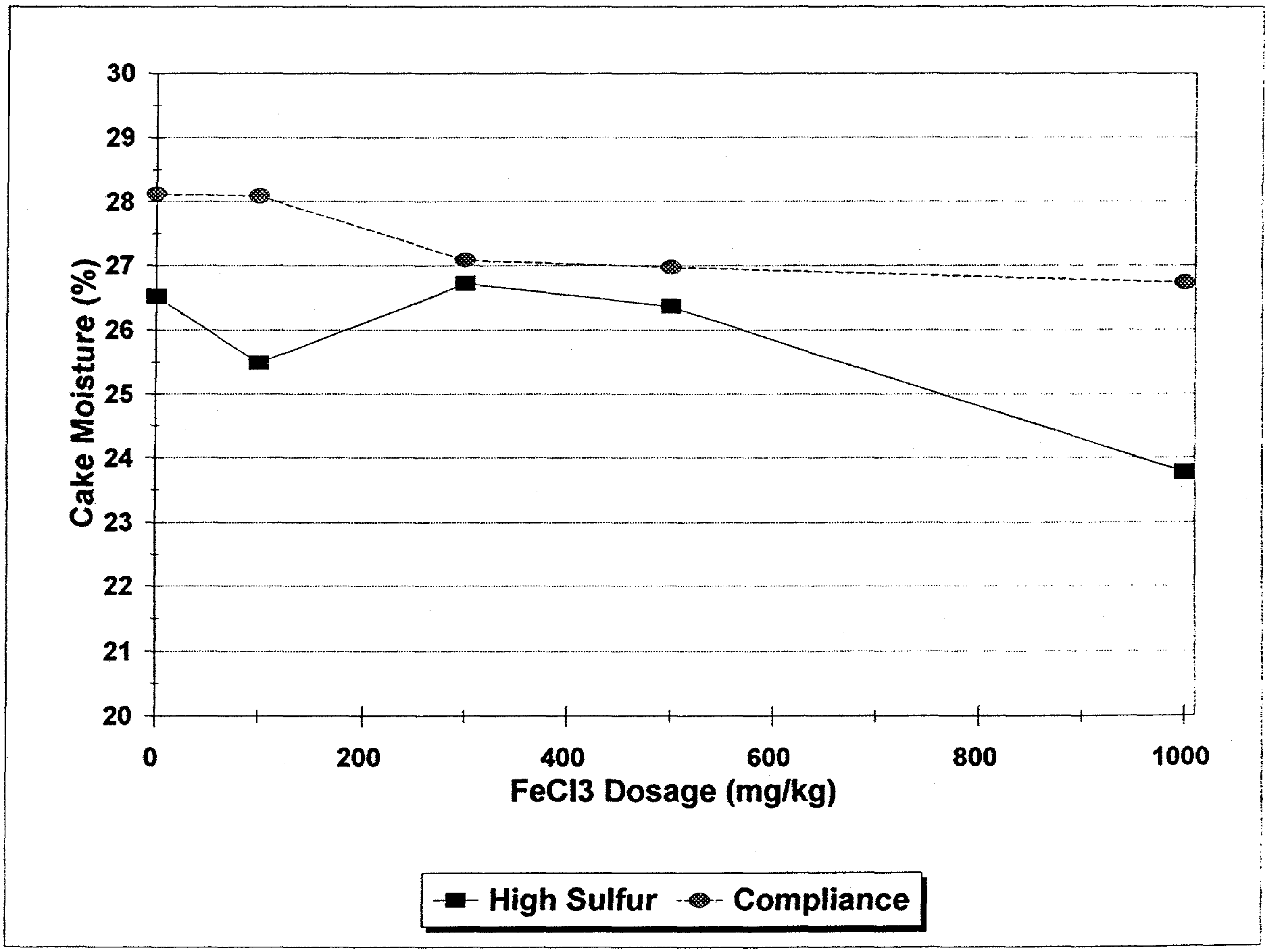

Figure 40. Effect of $FeCl_3$ Dosage on Cake Moisture for POC Testing with High Sulfur and Compliance Coal.

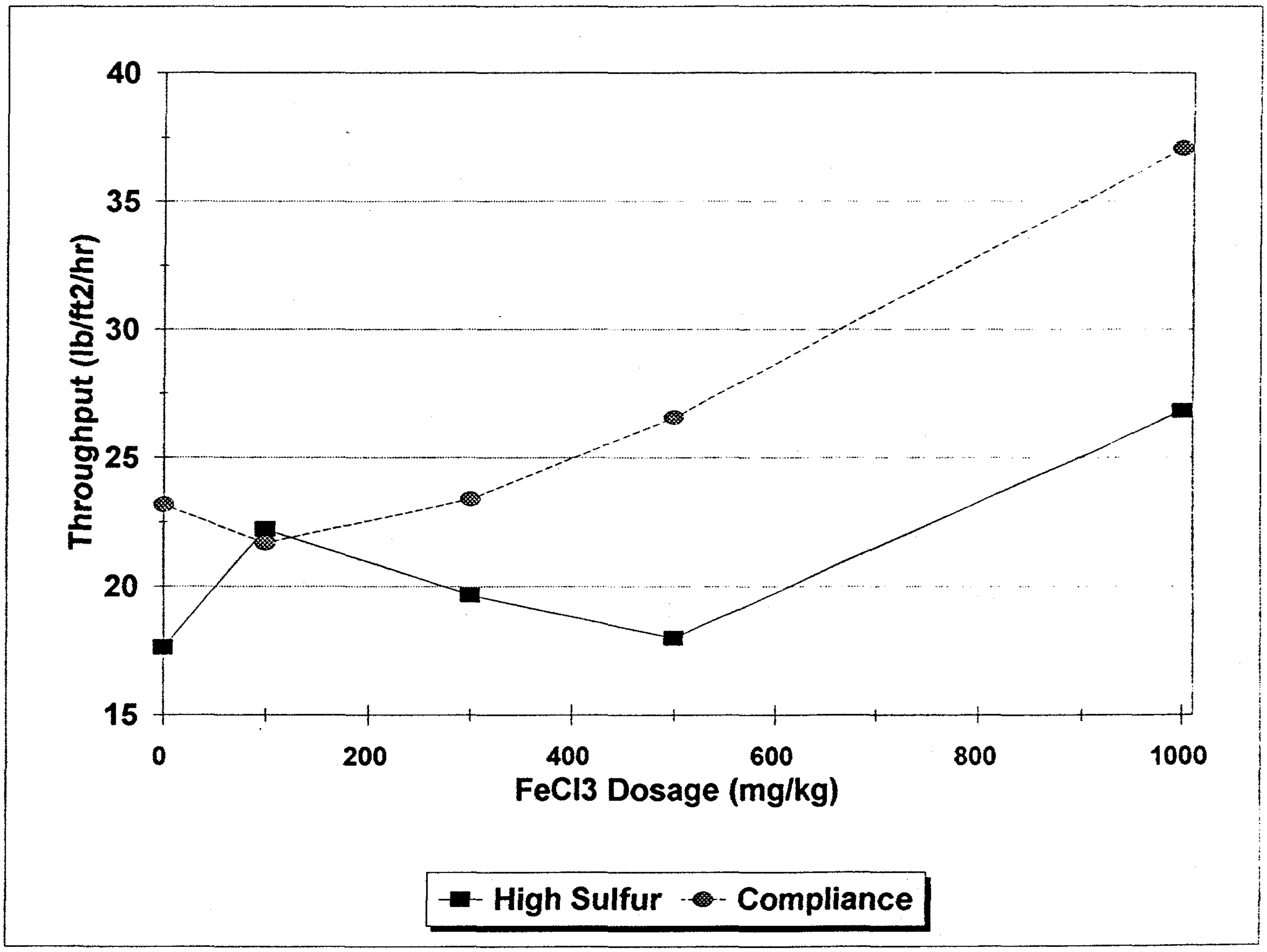

Figure 41. Effect of $FeCl_3$ Dosage on Throughput for POC Testing with High Sulfur and Compliance Coal.

compliance coal, throughput increased from 23 to 37 lb/ft^2/hr as the $FeCl_3$ dosage was increased from 0 to 1000 mg/kg.

The results of metal salt addition on cake moisture for the compliance coal are summarized in Figure 42. At a low dosage of 100 mg/kg, only $AlCl_3$ effectively reduced cake moisture from a baseline of 27.9% to 26.6% cake moisture. At higher dosages, $CuCl_2$ was the most effective, reducing cake moisture to as low as 26.2% at a dosage of 500 mg/kg. As shown in Figure 43, all of the metal salts tested effectively increased throughput for the complaince coal. At a dosage of 300 mg/kg, all of the metal salts provided throughputs of 24 lb/ft^2/ hr. The most notable increases in throughput were obtained at dosages higher than 300 mg/kg. $CuCl_2$ was the most effective at a dosage of 500 mg/kg, increasing throughput to 31 lb/ft^2/hr while both $AlCl_3$ and $FeCl_3$ provided approximately 27 lb/ft^2/hr throughput. At the highest dosage tested, both $CuCl_2$ and $FeCl_3$ provided throughputs of 37 lb/ft^2/ hr while the throughput achieved with $AlCl_3$ increased to 33.5 lb/ft^2/ hr.

For the high sulfur coal (Figure 44), $FeCl_3$ was the most effective metal salt for reducing cake moisture at very low dosage (100 mg/kg); moisture was reduced from 26.5% to 25.5%. At a higher dosage of 500 mg/kg, $CuCl_2$ was the most effective, reducing cake moisture to 24.8%. At the highest dosage tested, $FeCl_3$ was the most effective, reducing cake moisture to 23.7%. As with the compliance coal, the most significant changes in throughput for the high sulfur coal were observed at metal salt dosages higher than 300 mg/kg (Figure 45).

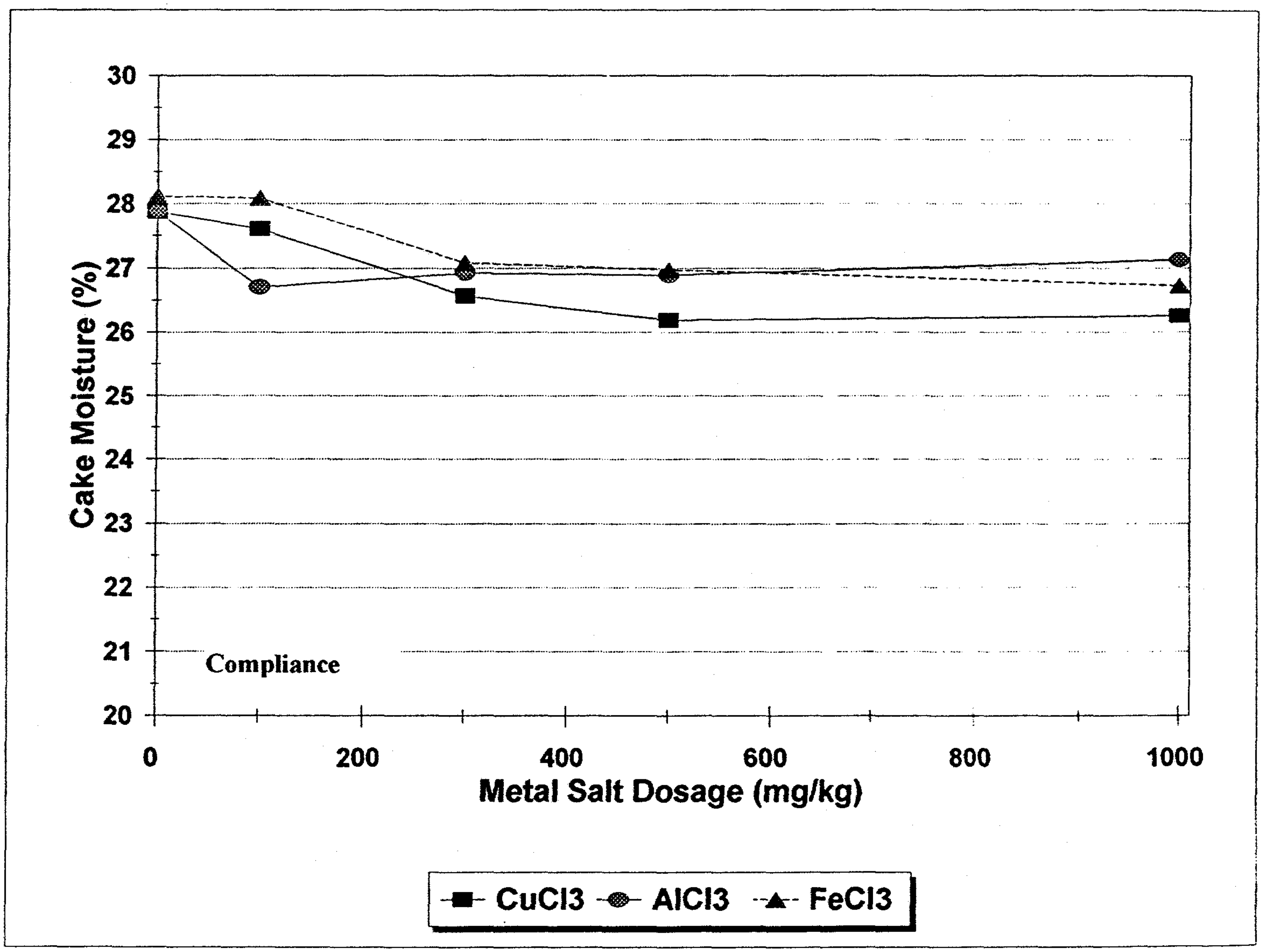

Figure 42. Effect of Metal Salt Dosage on Cake Moisture for POC Testing with Compliance Coal.

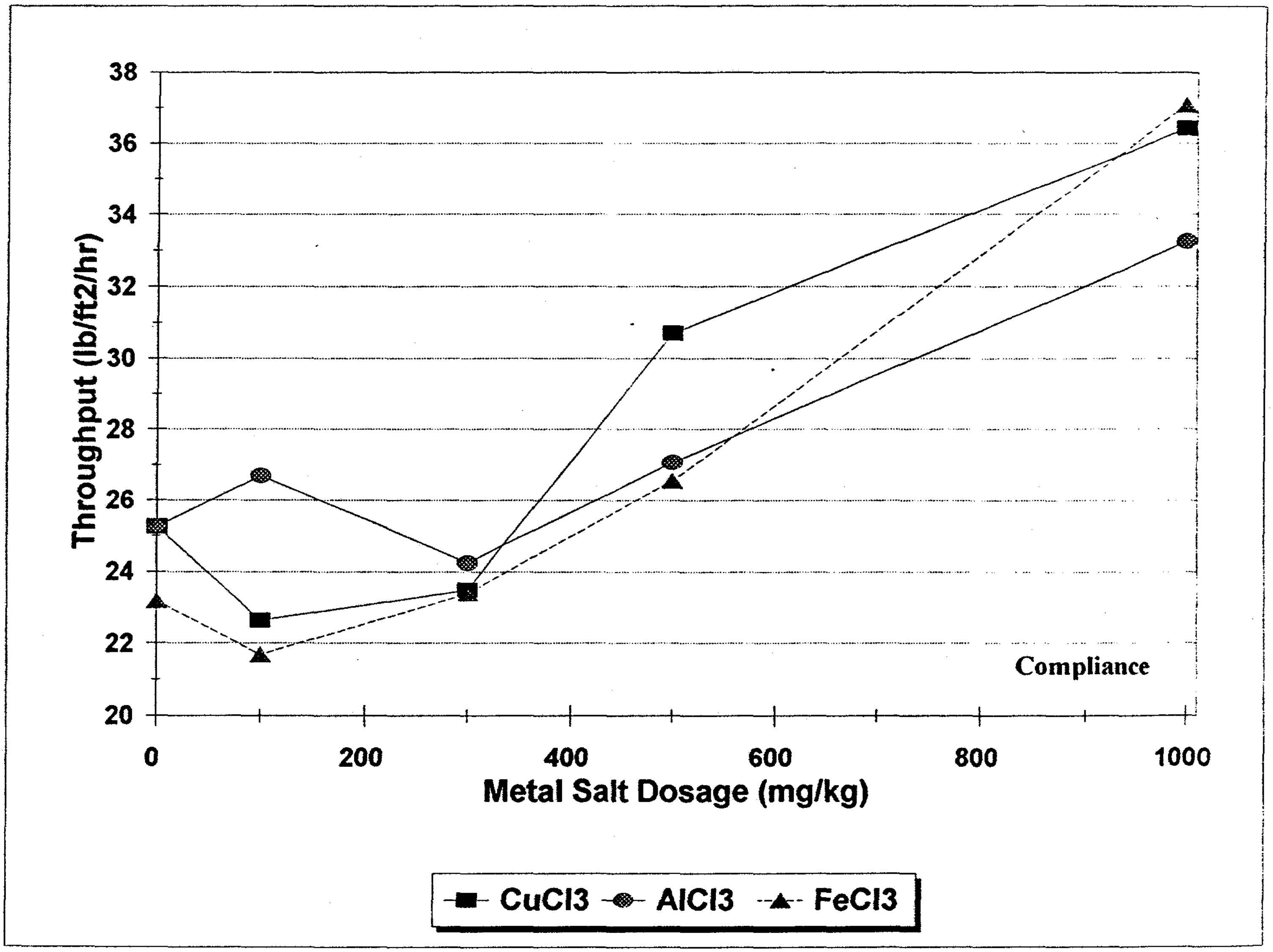

Figure 43. Effect of Metal Salt Dosage on Throughput for POC Testing with Compliance Coal.

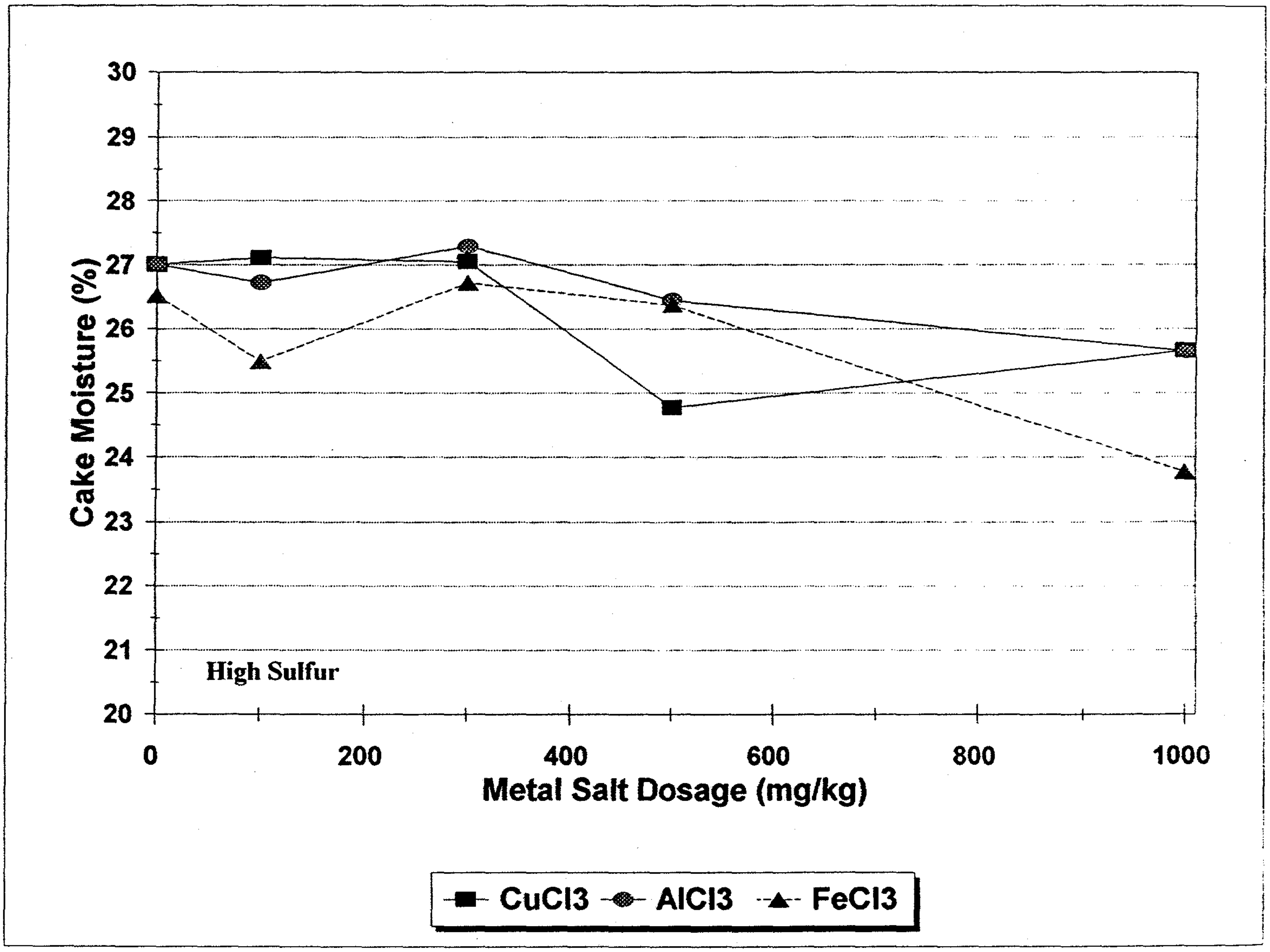

Figure 44. Effect of Metal Salt Dosage on Cake Moisture for POC Testing with High Sulfur Coal.

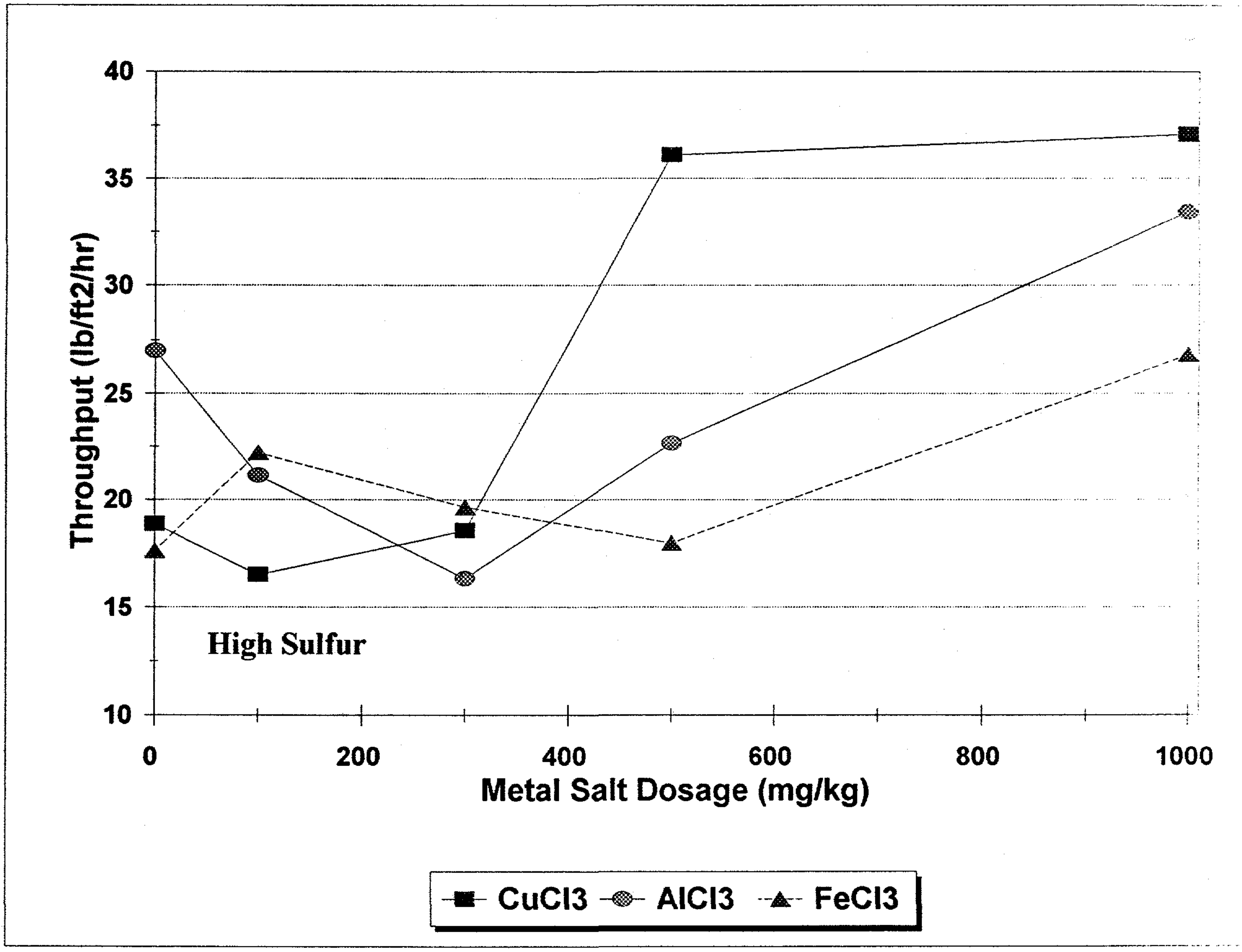

Figure 45. Effect of Metal Salt Dosage on Throughput for POC Testing with High Sulfur Coal.

$CuCl_2$ was clearly the most effective, more than doubling throughput from 17 to 36 lb/ft^2/hr at a dosage of 500 mg/kg. The addition of $AlCl_3$ actually lowered the throughput at low dosage (< 300 mg/kg), but increased throughput to 33 lb/ft^2/hr at a dosage of 1000 mg/kg in comparison of a baseline throughput of 27 lb/ft^2/hr. $FeCl_3$ also provided increased throughput at high dosage; throughput increased from 18 to 27 lb/ft^2/hr as the dosage was increased from 0 to 1000 mg/kg $FeCl_3$.

ACTIVITIES FOR NEXT QUARTER

Additional laboratory vacuum dewatering tests will be conducted in the next quarter. Reagents to be investigated include cationic surfactant and polymer. Synergetic effects of surfactant and metal ions on filter cake will also be studied. In-situ polymerization will be explored as a new technique for enhancing fine coal dewatering.